付 属 資 料

Preliminary Report

Flores Island, Indonesia Earthquake

of December 12, 1992

- Preliminary Investigation and Recommendations -

by

Japanese Expert Team

as dispatched by the Japanese Government

through Japan International Cooperation Agency

(JICA)

December 28, 1992

TABLE OF CONTENTS

I. Introduction

This report briefly describes the activities of the Japanese Expert Team dispatched by the Japanese Government through the Japan International Cooperation Agency (JICA) to cooperate with organizations related to earthquake and tsunami hazard in Republic of Indonesia in estimating the effects of the Flores Island, Indonesia earthquake of December 12, 1992 in the rehabilitation and recommendation of damaged structures.

This report also includes preliminary recommendation for the earthquake preparedness in the future.

A final report will be prepared later based upon detailed analyses of the data and information because the stay is Indonesia is quite limited.

II. Members and Itinerary

インドネシア地震国際緊急援助隊（専門家チーム）メンバーズ・リスト
JAPAN DISASTER RELIEF TEAM (EXPERT TEAM) EARTHQUAKE IN INDONESIA

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団 長	阿 部 勝 征 Mr. Katsuyuki ABE	東京大学地震研究所教授 PROFESSOR, EARTHQUAKE RESEARCH INSTITUTE, UNIVERSITY OF TOKYO	総括 LEADER
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SCHEDULE

DATE	TIME (local)	MATTERS FOR INVESTIGATION
20 Dec.	13:00-18:40	Tokyo ⇨ Jakarta
	20:00-22:00	Meeting with Embassy of Japan and JICA
21 Dec.	08:30-09:35	Ministry of Public Works (Mr.Kartomo : Secretary)
	10:00-12:00	Ministry of Mining and Energy Ministry (Director General : Dr. Adjat Sudradjat)
		Ministry of Social Wealfare (Director for Disaster Affairs : H.R. Djajusman)
	13:00-15:00	Embassy of Japan
	15:30-16:30	Press Release to Japanese Media
	17:00-18:00	Ambassador of Japan
	18:30-20:30	JICA Meeting
22 Dec.	04:30	President Hotel ⇨ Airport
	10:08-14:50	Jakarta ⇨ Maumere
	16:20-16:45	Maunere ⇨ Babi Island
	16:45-17:05	Survey (Babi Island)
	17:05-17:30	Babi Island ⇨ Maumere
23 Dec.	07:10-07:30	Maumere ⇨ Ende
	07:30-12:00	Survey (Ende)
	14:50-15:15	Ende⇨ Maumere
	16:00-18:00	Survey (in and around Maumere)
24 Dec.	09:00-11:00	Bupaty of Sikka
	11:00-18:00	Survey (in and around Maumere)
25 Dec.	09:00-17:00	Survey (in and around Maumere)
	17:00-19:00	Bupaty of Sikka
26 Dec.	14:15-20:00	Maumere ⇨ Jakarta
	20:45-23:00	Meeting with Embassy of Japan and JICA
	23:00-	Report Making
27 Dec.	06:00-	Report Making
28 Dec.	09:00-09:30	Ambassador of Japan
	10:00-10:30	Presentation of the Report to the Minister
	11:00-15:00	Meeting with related organization in Indonesia
	16:00-17:30	Press Release to Japanese Media
	18:00-20:00	Meeting with Ambassador
29 Dec.	22:00-07:00	Jakarta ⇨ Tokyo

III. Comments on the Earthquakes, Tsunami and damage.

1.Main shock and Aftershock.

1.1 Introduction of The Flores Island

The Flores Island are narrow, long islands extending the east-west wards, with 12 - 70 km widths and 360 km length, belonging to the Indonesia Islands Arc. Approximately 1.4 million people live in the Flores Island There are impressive volcanoes, beautiful lakes, forests, etc. The island is counted one of the most beautiful places to visit in Indonesia.

According to the modern plate tectonics, the island is located on the Asian plate along the plate boundary between the Asian and the Indo-Australian plates, where the Indo-Australian plate subsides approximately northwards beneath the Asian plate (Fig.1.1).

The Flores Island is geologically young and active because of subduction of the plate. The surface geology of the island primarily consists of Quaternary, volcanic rocks and Tertiary, volcanic rocks, including several volcanoes covered with younger Quatemary, volcanic products.

1.2. Seismic activities and earthquake disasters in Indonesia

The main islands arc in Indonesia is situated on a seismically active belt on the earth. The activity is based on the subduction of the Indo-Australian plate beneath the Asia plate.

Earthquakes with magnitude equal to or greater than 7 with or without tsunamis which caused damage to the Indonesia people are selected by the Japan Meteorological Agency in and around Indonesia (10°N - 20°S, 90° - 130°E) since A.D.1900 (Fig.1.2). Table 1.1 shows selected destructive earthquakes with M=7 or more in Indonesia.

In the period of 90 years up to 1990, the total number of death caused by earthquakes with or without tsunami is 983 in the table. Out of 983, 790 (80%) are caused by tsunami associated earthquakes. All disastrous earthquakes which caused more than 100 casualties are associated with tsunamis.

On 12 December 1992, an earthquake occurred off the north coast of the Flores Island and generated tsunamis. As the consequence total casualties exceeded 2000 as of 26 December 1992. The present 1992 event caused the great number of casualities ever experienced since 1900.

It must be recognized that tsunamis are really disastrous for the people of Indonesia.

Appended papers are a catalog of destructive earthquakes in the world, 1500 - 1992 compiled by Tokuji Utsu, Professor Emeritus, University of Tokyo, in 1992.

1.3. The 12 December 1992 earthquake

The earthquake occurred on 12 December 1992 off or on the north coast of the Flores Island where there was no earthquake with magnitude equal to or greater than 7 since A.D.

1900. The source parameters are calculated as following:

BMG (revised)	NEIC
8.6°S	8.43°S
121.9°	122.30°N
(Mb=6.8 $\pm$ 0.4)	Ms = 7.5
The mechanism is not determined.	Thrust fault with approximately north-south compression Paxis : Azimuth 351° Plunge 15°

BMG : Meteorology and Geophysical Agency, Ministry of Communications Indonesia.

NEIC : National Earthquake Information Center, United States Geological Survey.

This earthquake is low angle reverse fault and thought to be caused by back-arc thrust behind the arc rather than subduction of the Indo-Australian plate. The back-arc thrust is recognized as illustrated in the Seismotectonic map of Indonesia issued from the Geological Research and Development Center in 1992.

1.4. Aftershock activities

Aftershock activities have been monitored by temporary, portable stations installed in Maumere City in the Flores Island, where a large amount of damage is reported, and the city is probably the nearest city to the source area. The stations are operated by Geological Research and Development Centre, Ministry of Mines and Energy. Epicentral distances for the aftershocks are estimated to be 20 - 50 Km from the S-P times 3 - 7 sec. The number of aftershocks counted at the temporary stations are exactly decreasing as shown in the next table.

Date		Frequency	The maximum magnitude
December	13	34	6.0
	14	28	5.5
	15	18	4.9
	16	11	4.0
	17	18	5.7
	18	9	3.0
	19	7	4.5
	20	6	4.6
	21	4	4.5
	22	4	4.5

Such decreasing numbers mean termination of the present seismic activities.

Special distribution of the aftershocks are, however, not determined yet because of insufficient instrumentation, although detailed spacial information on aftershock activities are extremely important.

1.5. Recommendation

Regarding the present seismic activities, information on detailed locations of the mainshock and the aftershocks is insufficient. What we need as basic knowledge about earthquakes and related disasters is information regarding locations, occurrence time, and magnitude of earthquakes.

Therefore, seismic observation for aftershock activities carried out near the source area are very urgent. Such observation should be carried out, using high sensitivity five or more sets of seismometers with accurate timing systems.

More dense seismic observation network is required to locate the hypocenter in good accuracy. At least the three-component seismometer should be equipped at each station and telemetry system is also necessary for real-time data processing. In order to examine the fault mechanism, a few broad-band seismic stations are also needed.

It is recommended to install strong motion accelerographs on ground and structures for evaluating strong ground motion and structural response.

2.Overall Damage

2-1 Outline

(1)Damage extends over the each area of Sikka, Ende, Ngada and Flores Timur Regency. In those areas, damage in Sikka Regency was particularly bigger.

(2)Damage in Sikka Regency was remarkable in such cases as follows;

a.Damage by earthquake around the alluvial fun area formed by the River Kalimati which is located in the center of Maumere(Alok Regency).

b.Damage by tsunami around Wuring area in Maumere (the sub-urban area of Alok Regency).

c.Damage by tsunami on the Babi Island in Maumere Sub-Regency.

(3)Wide area of the town of Ende Regency suffered for severe damage by earthquake.

(4)In Flores Timur Regency, damage by Tsunanmi was bigger. Approximately two hundreds (200) persons were said to be killed by tsunami.

(5)Damage to building by the earthquake is mostly on the buildings made of bricks or stone masonry. Further more totally collapsed or heavily damaged buildings can be seen in the wide area of Sikka or Ende Regency.

(6)Damage by tsunami extends over at least one hundred (100) kilo-meters along the northern coast of Flores Island. Damage in the Wuring area and Babi Island of Maumere Regency and the east area of Flores Timur Regency on the Flores Island are bigger than others.

(7)There is no damage on the run-way of Maumere Airport(WAIOTI Airport, runway length one thousand and four hundreds forty-seven meters [1,470 m]) and Ende Airport(run-way length nine hundreds meters [900 m]). Therefore, both airports are available now. However, each control tower was heavily damaged. Both tower has been not available yet.

(8)Maumere port pier can be used as usual, though some part of shore protection work was hit by earthquake shock or tsunami and suffered for slight damage.

(9)The main road between Maumere and Ende is located in the mountainous area and several parts of that road was hit by landslides caused by earthquake. Because of that, the road traffic was torn into pieces here and there, and it cannot be used for going through.

(10)Phenomenon of liquefaction occurred over the wide area along the seashore of the northern part of Sikka or Ende Regency.

(11)Damage information by the Army Headquarters in Maumere(WAIOTI) Airport is as shown in Figure 2-1 and Table 2-1.

(12)The using number in the tables and each paragraph are not authorized. Therefore, there are difference numbers of the damage in the description.

2-2 Damage in Sikka Regency

(1)Sikka Regency got the biggest damage. Damage covered over almost whole area of this regency. About one thousands and one hundred (1,100) lives were lost and totally collapsed buildings came up to more than about eight thousands(8,000).

(2)Maumere Sub-Regency(Including Alok Sub-Regency), which is the main part of Sikka Regency, had gotten violent damage. Nine hundreds and thirty-three (933) lives were lost and the number of totally collapsed buildings reached over four thousands (4,000) and partially damaged buildings came up to three thousands and one hundred ninety-nine(3,199). These were the figures as of 8 PM, 23th Dec., 1992

(3)Remarkable damage in Maumere is on the buildings which are built in the main part of the town. The town spreads over the alluvial fun formed by the River Kalimati. Liquefaction occurred around these area. Most buildings collapsed and damaged are in the type of masonry structures.

(3)Conspicuous damage by tsunami occurred in Wuring, located in the west sub-urban area of Maumere, and also in Babi Island. The dead came up to eighty-seven in Wuring and about six hundreds(600) in Babi Island, respectively. Further more missing on Babi Island seems to be from fifty to one hundred (50 - 100) persons. Therefore there is no person living on Babi Island now.

(4)The main road connecting with Maumere and Ende is located in the mountainous area and was hit by many landslides from earthquake. As a result, about Twenty-one (21) places were cut off and the road cannot be used for passing through. Especially, about fourteen kilo-meters (14 km) road section between Muni and Ende have gotten heavy damage and eleven (11) places were cut off here and there.

(5)In Maumere, a number of main wells had been destroyed. Because of that, the water supply could not be used for three days after earthquake occurrence. And service reduction of supply is more than half before the earthquake occurrence. These were the figures as of 24th Dec. , 1992

(6)The situation of damage is as shown in Table 2-2.

2-3 Damage in Ende Regency

(1)Damage covered over the width area of the regency. Houses were collapsed and damaged by landslides occurred.

(2)The shock was more violent at the northern part of this regency, but the damage was small because population was little. Damage is remarkable around the area of Ende Sub-Regency and the vicinity.

(3)In the main part of Ende Sub-Regency, the dead came up to fifty-seven (57) and the damage to people houses reached to three thousands and six hundreds thirty-seven(3.637).

(4)The power generator did not get any damage. But the power line was cut somewhere. Because of that, electricity was not available for two (2) days. Water supply could not be used for a while, but it is available as usual, now.

5)There lives about one thousand (1,000) persons on the Palu Island in northern Ende Regency. tsunami attacked this island from south -east direction. But people live the opposite side, so that there was no damage by tsunami. But some larger landslides killed eight(8) persons.

(6)The situation of damage is as shown in Table 2-3.

3. Tsunami Behavior and Damage

3.1 Introduction

Large tsunami was generated by an earthquake of Magnitude 7.5 occurred off the Flores Island in Indonesia at about 13:30 on December 12 in 1992. Extensive coastline near Maumere on Flores Island was damaged by this tsunami. Particularly on Babi Island located about 10 km east of Besar Island, 750 people were killed out of total population (950) of the village and the village was totally demolished. This report summarizes the results of the field observation of tsunami inundation height at several locations, tsunami damages in Babi Island and Wuring, where severe damages were observed. Furthermore, future planning of the countermeasures against tsunami and useful recommendations are given.

3.2 Investigation of Tsunami Inundation Height

Field observation on tsunami inundation height was carried out between Dec.23 and Dec.25 along the coastline of Flores Island as well as the Babi Island. The inundation height was measured by a staff and a handlevel. Since the reference level of the ground is not known, vertical height of the inundation was measured with reference to the sea level at the measuring time. Therefore, measured inundation height is the relative value at the changing sea level condition.

The sign of the tsunami inundation was clearly read on the outside wall of houses at many locations in Flores Island. On the other hand, on Babi Island the inundation height was measured based upon the height where floating debris attach to the trees, since all houses were destroyed by tsunami.

Figure 1 shows the location map of the observation sites and the inundation height in meter as well as the observation time. Although the correction of sea level change is necessary, maximum value of 2.75 m was measured at Wuring and Maumere in Flores Island for the wave run-up height. The tsunami height decreases from these areas to east because of the sheltering effect of Besar Island, and to west due to the existence of the offshore reef as shown in Fig.2. In Babi Island maximum inudation height was about 3.4 m, and it is larger than that at Wuring.

3.3 Consideration on Tsunami Damages

Although tsunami brought many casualties in wide area, most characteristic damages due to tsunami can be observed in Babi Island and Wuring. In Babi Island 750 people died out of 950 living in this island and only 200 were able to escape from tsunami. Similarly, death toll of 79 was confirmed at Wuring. In the following some considerations are made taking these cases for typical examples.

(1) Babi Island

Babi Island is located about 40 km northeast of Maumere, and the diameter of circular island is about 2.5 km. Coral reef well develops around this small island as shown in Fig.3. Off the north shore of this island wide reef develops due to the incidence of wind waves, whereas it is narrow off the south shore. In addition, two large cuspate forelands develop on the south side of the island. These geomorphological features imply that the location receiving the most severe action by wind waves are north and northwest shores, and two cuspate forelands were formed by the depositional effect of the coral debris carried by the longshore currents around the island. Accordingly, the foreshore and backshore height of the sandy beach in two cuspate forelands are of the order (1-1.5 m) of the run-up height of diffracted waves in the lee-side of the island.

Tsunami front invaded these sandy beaches from south, where water depth is very deep since the coral reef does not exist. By this tsunami attack all buildings of this village were destroyed. The direction of the tsunami movement can be confirmed to be from south to north by the following observations:

1) Debris of the houses were scattered in the palm trees north of the original positions as shown in Fig.3.

2) Palm trees were fallen down by tsunami with their roots heading north.

3) An eyewitness from this disaster pointed out that the tsunami came from south.

As mentioned above, wide reef develops on the north shore of Babi Island with poor development of coral reef on the south shore. In addition bottom slope of the south shore is very steep. Since the cuspate foreland protrudes and wind waves incident from north are well protected by the island itself, the lee-side of the island has been used for the anchoring harbor. However, it is evident that this becomes a weak point for tsunamis. If shore protection facilities are built around the village on the sandy shore, it is considered that tsunami disaster did not take place. In fact, the village was totally devastated because of the lack of the shore protection facilities.

(2) Wuring

Wuring is located about 2 km northwest of Maumere. Here many houses of raised floor were destroyed and many boats were scattered on land. Final death toll was 79. The causes of tsunami disaster at Wuring can be summarized as follows:

1) This area is located outside of the shelter zone by Besar Island.

2) It was not protected by shallow coral reef as the coastline west of this location.

3) Village is located at the western shore of U-shaped bay, where generally tsunami height increases by Green's effect.

4) Many houses of raised floor were built in the low land.

Above mentioned two examples can be summarized as follows. Generally speaking, tsunami damages are not large in the coastal zone of relatively high ground elevation. In the case of the Babi Island, the ground elevation was 1-1.5 m, originally formed by the depositional effect of wind waves on the foreshore, and this is lower than that in Maumere Port. This is the main difference of the causes of tsunami disaster. Similarly, at Wuring many houses were built on the ground elevation lower than 1 m. This again causes severe damages against tsunami of 3 m high.

3.4 Measures against Tsunami

In this section countermeasures against tsunami are discussed. taking Babi Island for an example. After the tsunami all inhabitants in Babi Island evacuated to Flores Island, and no one lives in this island at present. However the number of the people returning the island will increase with time, since many people in this island have been living by fishery. And in the long-term a village will be formed again. Thus the generation of tsunami causes the same disaster in this island. In order to solve this problem without the abandonment of this island, it is necessary to build coastal dike along the shoreline. Figure 4 schematically shows the idea. The coastal dike connecting the both ends of the hill side should be built along the shoreline on the sandy beach. Some important points regarding this project are as follows;

1) The front slope, crown and back slope of the coastal dike should be made of concrete. The necessary thickness of the concrete is over 30 cm.

2) The crown height of the coastal dike should be about 3 m above the mean sea level, by considering the measured maximum tsunami run-up height (3.4 m). This means that the designed crown height is a little lower than measured tsunami height. Since the construction of the coastal dike of high crown height is expensive, the structure which is not destroyed by tsunami overtopping or overflow is needed for the coastal dike.

3.5 Recommendations

(1) Must evacuate from potentially dangerous area for tsunami as rapidly as possible after the earthquake. It must be strictly prohibited to approach to the shoreline to see the tsunami or the movement of boats.

(2) The village in Babi Island was protected for the wind waves because of its location in the sheltered area of the island itself. However, it does not necessarily mean for the safety against tsunami. In Indonesia there are many islands having the same natural conditions as Babi Island. It is advisable to check the safety of these islands against tsunami.

(3) The forests formed by palm trees or other trees must be protected because they are useful for reducing tsunami energy.

(4) In the locations where high tsunami run-up was observed such as in Maumere, some signs showing the inundation height (usually recorded on the outside wall of the houses) should be noticed in order to inform people of the danger of the tsunami and not to forget the tsunami disaster.

(5) When people must live in the potentially dangerous area for tsunami as in the case of Babi Island, it is recommended to build shore

protection facilities such as the coastal dike along the shoreline.

4. Damage To Buildings

4.1 Observed Damage

Ende City

- The population of Ende is around seventy thousand. 229 persons were dead in Ende prefecture, and 25 persons were dead in the city area according to explanation of the Governor of Ende prefecture.
- Damage ratio of total numbers of buildings seemed to exceed to 50%
- Many of buildings are red coloured brick masonry structure and their numbers of 2 or 3 storey buildings are very few.
- Concrete blocks structures are appeared not so often and they were also damaged severely
- Some of buildings are reinforced concrete with masonry wall structure. However size of column section is very small; seize of 15 centimeter by 15 centimeter are typical dimensions.

  Total number of dead people in Ende prefecture was 229 reported on 22nd December '92. 25 persons in Ende city area were killed due to collapse of buildings.
- Reinforced concrete buildings with masonry walls were also collapsed but its collapse ratio to total number was not so large.
- 1543 buildings were damaged (collapse, severe damage, slight damage) due to earthquake in Ende prefecture. The population of Ende city is about 70,000.

Maumere City

- Maumere Prefecture lost around 600 people due to Tsunami and 244 people were dead due to collapse of buildings by earthquake.
- Many red colored masonry housings were collapsed especially near to Dead River ("Kari Mati")
- Especially west side of city area along the coast is alluvial layer. Buildings on its layer were so much damaged
- Comparatively new masonry buildings have reinforced concrete framing. However their size of members were very small
- In severely damaged commercial area, some of reinforced concrete buildings with masonry walls slightly damaged. In this area, the collapsed ratio of reinforced concrete buildings is small.
- Jl. Rajasentis towards fish market, has around 60 building. As long as from this road, 16 buildings were collapsed and 30 buildings were damaged.
- At the southern part of the main street Kartini street (crossed east an west in this city), reinforced concrete water tank was not severely damaged. Its height is about 15 meters and its four columns were 30cm X 30cm cross section with 10 cm covering mortal.
- East side of city was not so much heavily damaged.
- The damage of road was not so much distinguished.

4.2. Recommendations

- As the most emergent measure, it is required to fulfill school's function. Small sheet tents were set at almost of all damaged buildings. However big size sheets were not sold in Maumere city. At least one hundred tent sheets (10m x 10m) for temporary class room and black board etc were urgently required.

In case of masonry structure, the stopping device for out-of-plane falling down of masonry wall is very important. To the damaged buildings, the assumption of rigid floor slab system can no be used. Seismic integrity of total structural system should be carefully considered.

5. Damage of Lifeline Facilities

5.1 Introduction

Roads, bridges, port, airport and utilities are the essential structures for life of people, and is therefore often referred to as the lifeline facilities. Features of the damage of those facilities are described in this section.

5.2 Damage of Roads and Bridges

Extensive damage was developed in roads and bridges in Flores Island. Major damage was concentrated on the National Road connecting Ende and Maumere and Maumere and Larantuka, and the Provincial Road connecting Maumere and Megapanda. Although there are many other damages on local roads, they have not yet fully surveyed.

Feature of the damage depends on the geological, topological and soil condition at the site. Typical damages are as :

(1) National Road from Ende to Maumere

Inspection was be made from Maumere to Lekebal. Although it is said that several bridges suffered extensive damage, it could not be inspected. Because the road crosses the mountainous site, many slope failures were developed.

Because the surface at the site is deeply covered by soils, slope failure associated with soil mass was developed. Although rock fall was also observed, it is not so frequently observed between Maumere to Lekebal. They were weathered lime stone and sand stone.

Fig. 5-1 classifies the type of failures inspected. Four types of failure were observed. The Type 1 Failure in which the cut slope slided on to the road could be seen most frequently. The Type 2 Failure in which not only the cut slope but the natural slope failed were also widely observed. At the site where one side was cut and the other side was embanked, the pavement of the filled embankment side often settled and this caused cracks on the pavement (Type 3 and Type 4). The Type 5 Failure in which the slopes both on and under the road slided was also observed.

The damage became significant because the soils are of soft and wet clayey materials (volcanic ash). Scoria was observed at about 2 meter below the surface at a couple of sites. At those sites, the failure was induced at the scoria layer. Therefore, attention needs to be paid to survey the distribution of the scoria.

(2) National Road from Maumere to Larantuka

Extensive damage of pavement and bridges were developed by soil instability. There are two types of bridges. One is the one-lane and small-span bridge. They are mostly single span or two span simply supported girder bridges. This type of bridges are very old, and were probably constructed before the Second World War. The second type of bridges are rather new. They are steel truss girder supported by reinforced concrete single columns or flame piers. The damage was mostly observed at the old bridges.

Fig. 5-2 shows the typical damage of the bridge on this route. The most common type of failure was the settlement of back soils. However, this type of damage is nothing to do with the failure of the bridges, and can be easily repaired. The second type (Type 3) of the damage was developed due to tilting of the abutment in the deck side. Contact of the abutments with the deck caused cracks at the abutment, because the deck resisted as the lateral beam between the two abutments. Some of them were therefore extensively damaged and require full restoration. The third type (Type 3) of damage was the sliding of foundation to the deck side resulting the tilting of the abutment in the back fill side. A large settlement of the girder was also observed. This is the critical damage because the tilting of the abutment in this direction tends to result falling down of the girder. Therefore full restoration is advised to be made promptly for this type of failure.

It should be noted that such tilting and sliding of the abutment was mostly caused by sliding of surrounding soils as shown in Fig. 5-3. The difference of the Type 2 and Type 3 damage was attributed to the difference of depth of soil sliding. When only shallow soils slided, the abutments tend to tilt in the deck side, while when the sliding occurred deeply, the abutments tilted in back soil side. It is important to know that this is the damage caused by not vibration of the deck and abutment but the soil instability due to the earthquake. Therefore it is important to properly consider such instability of surrounding subsoils into seismic design of bridges.

The seismic performance of the new truss bridges were basically good. The damage observed was the failure of anchor poles and cracks of parapet walls. The rubber cushion placed at the end of the deck behaved quite well for reducing the impact between the deck and the abutment wall. Although damage of abutment walls were observed at several bridges, they can be considered as small damage for such a large earthquake of DEcember 12, 1992. However at one bridge near Nebe, the lower cord (H-beam) at the first panel of the truss was buckled probably due to collision of the deck with the abutment. Because this is the main member, it is required to replace the lower cord promptly.

The soil unstability caused the cracks on pavement at several sites. Depending on the size and degree of the soil sliding, the pavements suffered cracks in longitudinal (parallel to the road) and transverse direction.

(3) Provincial Road from Maumere to Megapanda

Along the Provincial Road from Maumere to Megapanda, there were several cracks and settlement of pavement associated with soil liquefaction. The largest settlement was at 15 km west of Maumere, and was as deep as 1m. At this site, many sand valves associated with soil liquefaction were observed. The largest sand valve had the diameter of 2.1 m and the depth of 1.2 m.

Special interest was the cracks of pavement observed near Maumere Port. As shown in Fig. 5-4, the cracks were developed along the road parallel to the coast. Although there were several lines, they were essentially continuous. This clearly shows that a large sliding of top soils as well as the settlement as shown in Fig. 5-4 was developed along the coast.

5.4 Damage of Airports

The Control Tower of the Maumere Airport and the Ende Airport were badly damaged. The Control Tower at the Maumere Airport was four story masonry building, and was subjected to extensive shear failure at the wall with the glass being broken. The control Tower at Ende Airport was three story masonry building, and was suffered significant shear failure at the wall. The damage was so extensive that they could not be used.

However, the apron and run-way suffer almost no damage at both Airports.

5.5 Damage of Ports

The Maumere Port suffered extensive damage due to soil liquefaction and Tsunami in addition to the ground shaking effect. The quay wall and retaining wall for the apron was overturned toward sea side and was badly damaged. There were several ruptures , which was developed due to soil liquefaction, on pavement at apron.

Soil liquefaction also cause extensive settlement and tilting of several buildings at the port.

5.6 River Hydraulic Structures

A water barrier on a river near Nebe suffered damage on the parapet wall of water gate. The parapet wall was tilted with the back side being apart from the soil. Deep cracks were developed at the back soils along the wall. Leakage of water from the parapet wall was seen. It is therefore required to study the water path for preventing the possible increase of the leakage.

5.7 Damage of Utilities

The damage situation of the electricity, telephone, water, sewer and gas is not well known. The only information obtained during the survey is as ;

At Ende, the electricity is generated by 7 diesel engine generators. They did not suffer damage. The building storing the generators suffered moderate damage ; masonry wall fell down at two locations. Although this was critical, because cables distributing electricity were ruptured at several points, the electricity was suspended after the earthquake. But it was rapidly repaired.

The water distribution was interrupted at wide area in Flores Island. The water is therefore delivered by a water-tank vehicles.

5.8 Strong Ground Motion

Although it is said that 57 strong motion accelerographs are installed in Indonesia, no information regarding the location of the accelerographs and the strong motion records by the earthquake was obtained. Because the strong motion record is one of the most essential information for evaluating the intensity of ground shaking and structural response, it is advised to establish a system in which the information of strong motion records can be available.

Because no measured information was available, the peak ground motion was assessed bade on the Japanese empirical attenuation equation. Based on the statistical analysis of 394 components of strong motion record obtained at free field sites in Japan, the peak ground attenuate with the epicentral distance as ;

$$a_{max} = 232.5 \times 10^{0\ 313M} \times (\Delta + 30)^{-1\ 218} \qquad (5\text{-}1)$$

where,

a_{max} : peak ground acceleration (cm/sec^2)

M : earthquake magnitude in Richter scale

Δ : epicentral distance (km)

Eq. (5-1) represents the peak ground acceleration on medium soil site. It should be noted that Eq. (5-1) provides the mean value and that the scatter around the mean value is considerable. If one considers the deviation from the mean value equivalent to the one standard deviation, the empirical estimation becomes either 1.7 times or 1/1.7 times of the mean value predicted by Eq. (5-1).

Assuming that the earthquake magnitude M of 7.5, the peak ground acceleration predicted by Eq. (5-1) attenuates as shown in Fig. 5-5. Because the epicenter of the earthquake was 8.43 degree S and 121.30 degree E, the epicentral distance of Maumere was about 50 km. It should be noted here that because the fault zone is very close to the Flores Island, it is not appropriate to evaluate the distance from the fault zone to the site in terms of the epicentral distance. However if one considers 50 km for the epicentral distance at Maumere, the peak ground acceleration is evaluated as 0.25 g. This value is considered to be a first-hand evaluation for the ground acceleration during the earthquake of December 12, 1992.

5.9 Soil Liquefaction

Soil liquefaction was developed extensively along the coast of Flores Sea. It is well known that the saturated alluvial sandy layer which has the water table within 10 m from the ground surface and has the D_{60}-value on the grain size accumulation curve between 0.02 and 2.0 mm are vulnerable to liquefaction.

Fig. 5-6 shows the soil profile at two sites near Maumere. The point 1 is located south west of Maumere and is about 1.5 km apart from the coast while the point 2 is located south east of Maumere and 1.8 km apart from the coast. The ground condition is similar at the two sites, and is of sandy soils with the thickness of about 30 m - 50 m overlaid by the top soil with the thickness of about 5 m. Although grain size curve needs to be precisely investigated, the sand obtained from the sand valves has the predominant grain size of 0.1 to 0.3 mm. Because water table is very high, it is considered that the sand near Maumere is quite vulnerable to liquefaction.

It is also known that the area in which liquefaction is induced increases as the earthquake magnitude increases. This relation is empirically obtained as

$$\log \Delta = 0.77 M - 3.6 \qquad (5\text{-}2)$$

where,

M : earthquake magnitude in Richter scale

Δ : epicentral distance (km)

Fig. 5-7 shows the empirical relation by Eq. (5-2). It is not surprising from the past experience to have the liquefaction within 150 km from the epicenter for the earthquake of December 12, 1992.

5.9 Recommendations

Based on the survey for the lifeline facilities described above, it is recommended as ;

1) It is recommended to carefully inspect the substructures of bridges with the major attention to the damage of substructures in Flores Island. For those bridges which suffered damage to the abutments in such a manner that the foundations slided to the deck side direction with the top of the abutment being tilted to the back fill side, it is recommended to fully replace the abutment as soon as possible to avoid the possible falling down on the girder. Because those bridges are very old with only one lane, evaluation needs to be made whether

they should be repaired or replaced with new structures.

2) Because there are a number of bridges in Indonesia which were constructed at the age when the seismic effects were either disregarded or insufficient, it is recommended to develop the simple seismic evaluation method of existing bridge structures. The evaluation method has to be as simple as possible so that inspection be made at the sites. The evaluation of the seismic stability of substructures may be the key item to be considered. A master plan for seismic evaluation and possible strengthening of existing bridges may be important as a future plan.

3) Although it is generally very difficult to prevent the failure of cut and natural slope along the road in mountainous area, it is recommended to investigate the possible measures against slope failure from cost and effective point of view. It is advised at this point to widen the road so that at least full two lanes of traffic be guaranteed. This may be effective to provide a space to store the falling soils and rocks from the above of the road during an earthquake. Covering the slope above the road by concrete mortar may be effective to prevent the weathering.

4) Because road network in Flores Island is very poor, it is recommended to establish a master plan of future road network so that the major cities be prevented from isolation from other areas by an interruption at one location. Such a master plan may be very important for developing the Flores Island.

5) For restoring the Maumere port, it is recommended to consider the soil liquefaction effects in design. Some treatment for preventing the failure of the retaining wall may be effective to reduce the damage of wall and apron. It is also recommended to consider the soil liquefaction effect for reconstruction of important buildings in the port.

6) It is recommended to establish a system to systematically conduct the strong motion observation including the maintenance system. This may be very important to evaluate seismic design force and to evaluate soil and structural response during an earthquake.

6.Landslides, slope fialures, collapses and soil liquefaction

6-1. General descriptions of geology in Flores island

The small Sunda islands consists of several islands. Most of them are volcanic islands. And these islands are also raised coral reef islands of which surface are covered by volcanic materials, for example, by pyroclastic flows and complex volcanic fans. This area forms island arc from Sumatra island via Flores island to the end of Buru island.

Geology of the research area consists of mainly Tertiary and Quarternary rocks. Especially the area consists of tertiary and quaternary volcanic rocks in the western part of the area near Ende. And the other part consists of quaternary volcanic rocks.

The weathering of rocks in the area is remarkably developped and as a result, the are is very weak against natural hazards including landslides, collapses and slope failures of road sides and boulder flows caused by heavy rainfall.

6-1-2. Geomorphological characteristics

As for relief of the area, mountainous area (volcanoes) consists of very steep slopes and surrounding volcanic fans are very gentle and undulating. Near Ende, mountainous area consists of remarkably dissected river drainage system in which area there are many pinnate type of river systems with steep and summint recordance. The process of dissection and transportation are very strong to supply material from the upper drainage basin to the lowermost delta. And delta have been being formed still in the present very rapidly.

In the mountainous area, the reserchers did not find Sabo dams and long embankments along the rivers. This shows that in Flores island, natural fluvial process are still natural, but not deformed type of process like the one in Japan. This shows that landforms in lowlands are very young and in development.

In the area, river can transport much material from the upper darainiage basin and the lowermost deltas easily and can form very young layer of which subsoil is very soft. And mangrove forests are distributed along the coastline. This dis tribution also can easily form very soft layer along the coastline.

Followings are evidently clear in combination with geology, relief distribution, geomorphological characteristics, soil distribution map and aerial photointerpretation.

1) mountainous area consists of very fragile rocks which are weathered remarkably and can be easily dissected. 2) in the uuper drainage basin, Sabo constrcutions are not done, and as a result, rivers can easily transport much material to the lower draiagen basin. Rivers have natural forms still in the present.

Based on above mentioned facts, it is concluded that the research area is never strong against natural hazards.

6-2. Landslides, landcollapses, slope failures at roadsides

6-2-1. Landslides, landcollapses, slope failures at roadsides and boulder flows

The research was done by two groups from Ende via Maumere,

to Nebe and its surroudings. From Maumere to Nebe, we researched by a car in a three persons team.
And from Maumere to Ende, also another three persons` team researched using military helicopter.

A big earthquake often causes many slope failures including landslides, landcollapses and roadside slope failures.

This time, it was impossible to visit damaged sites on the road and to the sites of big collapses from Maumere to Ende by a car or using a helicopter. For the reason, we observed the distribution and characteristics of these phenomena.

6-2-2. Slope failures from Maumere to Nebe

The research of the area is limited only in the beltic zones along the coastal lines. The route was suspended for a few days for the traffics to pass after the earthquake. When we researched the route, it was possible to pass, but the recovery is still temporary repair.

This route is important one for inhabitants living in the damaged area. While JDR reserached the area, many cars, motor-cycles, people used the route. Especially, important for trans portation of goods and for schools and office workers to go and return their office and schools.

There were many sites of cracks of the pavement and a few sites of collapsed sites. A few of land copplases formed deposit area at each site which consists of volcanic pyroclastic flows (2) and limestone. At one of them, it is eveidently clear that land collapse was caused repeatedly in the past in the same site.

6-2-3. Slope failures from Maumere to Ende

Using a military helicopter, the followings are clear. But the followings are the result based on observation from the helicopter. For the reason, the followings are only a kind of preliminary general obsevation.

Various types of landslides, landcollapses, roadside slope failures were seen from Maumere to Ende. Some of them have been recovered already temporarily from Maumere to the near-south coast (near Tilan), and short distance from Ende toward inland. But most of other part is not recovered at all.

The earthquake caused many and various types of slope fail ures. These were caused at roadsides, slopes of mountainous area. Failures consists of two groups. One is new ones. Another is repeated
ones.

Slope failures are classified into several groups as shown in the folowings: (1) roadside slope failures, (2) surface collapses caused just under the break line of ridges, but single and continueing downward, (3) surface collapses caused just under the break line of ridge, complex collapses with broad width, (4)large colapses which forms a tail downward with deposit of reddish brown boulder, (5) small collapses with a head to tail, (6) landslides with many cracks at the top of slides.

(1) Roadside slope failures: Many small slope failures were

caused at roadsides from Maumere to Ende. Some of them have been already recovered. But about one third of the distance is still in recovering work. This type is classified into three. 1) slope failures at mountain side slope of the road, 2) slope failures including mountain side and valley side through the road, 3) slope failures at valley side.

Using oblique aerialphotographs from a helicopter, it is easily interpreted whether the landslides are active or not.

(2)and (3) are caused in mountain slopes without any relations to roads. For the reason, the interpreter must interprete more detail, for exmaple, using the condition of vegetation cover and other functions. And sometimes, these types are repeated types of collapses. These are caused at steep slopes of pinnate river drainage system in mountainous area with summit recordance.

(4) was caused in the surroundings of the valcano. This type of collapse has a large head (collapsed area) and a long tail (transportation route with deposit, and deposit area).

(5) were caused in steep slopes on the mountain ridges. In the research area, 0-order stream in a dendritic (tree) type. This type has a small head and very long and fine tail.

(6) were caused at the top of a little gentle ridges. There are many cracks at the top of the landslides.

6-2-4. Characteristics of slope failures

(1) The route between Ende and Maumere is important route for inhabitants and the route must be used at any time. And if some parts are suspended, the sites must be reopened in a few days to one week. The route has been formed through history without detailed design.

When road plans are made, the characteirstics of geology should be clarified to decide the gradient of the side slope, whether rocks are weathered or enougly hard,

(2) This time, we could find a few landslides with cracks, because we flied only along the route. If there are such landslides still in moving, the most important thing is to monitor the movement of the landslides using very simple method called `slope stake .

(3) It is one of the most effective way that civil engi neers and plannners use aerial photographs to interprete charac teristics of the land against natural hazards. For the reason, aerial photographs shouldbe more used for such purposes.

6-3. Soil liquefaction

6-3-1. Soil liquefaction

Soil liquefaction is a phenomenon as shown in the follow ings: Subsoil receives earthquke shock (repeated shearing). And pore water-pressure increases, subsequently effective stress de creases. And as a result, the sub-soil layer loses shear-strength.

6-3-2. Outline of soil liquefaction in the research area

Soil liquefaction in the research area were caused in many sites. Mainly the area where soil liquefaction were caused, is grouped into three. (1) Maumere city area including Maumere port and backward housing area, (2) Coastal zones including Wuring via Maumere to Nangorak, probably more broad area along the coast line. and (3) Babi island.

(1) Maumere: The most remarkable sites are the surroundings of Maumere port and its surroundings. Port facilities were dam aged. The aspects are typically seen in the port. Paved sites were also destroyed by soil liquefaction. Water with soil erupted out of the land surface and the site subsided and formed a hall.

At the backward of the Maumere port, in the housing area several houses were destroyed or partly damaged. One house was destroyed by erupted much water and sand. Inside of the house, much sand deposited. In addition to these examples, small liquefaction sites could be seen.

Maumere city are located on a very soft ground on which surfaces are pretty consolidated for many houses. Geomorphologically, the area is delta with reclaimed land surface with partly former river course.

(2)Coastal zones: In many points, soil liquefaction were caused along the coastline. In Wuring, which is located on a sand bar of which surface is consolidated for peoples' life, just after the earthquake, but before Tsunami, hot water with sand suddenly erupted out in many sites of Wuring.

As for the other part of the coastline, soil liquefaction were caused in many sites in a long shoreline facing Flores sea, at the higher part of backshore which is covered by vegetation or used for daily life. But, most of sand boils can not be seen except very few traces because erupted sand boils were washed away.

(3) Babi island: In Babi island, soil liquefaction were caused in many sites in sandy landforms. Most of them were caused in the area which were washed away by Tsunami, but some of them keep their form typically.

6.4 Recommendation

(1) The characteirstics of geology should be clarified when road plans are made whether the rocks are weathered or enougly hard to decide the gradient of side slope.

(2) 'Slope stake' is available to monitor the baheviour of landslides. This is very simple method.

(3) Aerial photointerpretation should be used more to compile various kinds of thematic maps for clarifying characteristics of the land and to catch natural disasters damages.

7. Emergency Countermeasures against Disaster

7-1 General description of Emergency Activities

(1) The system for emergency activities

1) When the large-scale disasters break out, the emergency operation system, which is consisted from the central government to the local government, will be established according to the decleration of President "Decree of the President of the Republic of Indonesia, Number 43, Year 1990, on the National Coordinating Board for Disaster Management"
In this case, also, according to this decree emergency activities are being executed under the cooperation of the central government, province, regency, sub-regency and armed forces of Republic of Indonesia(ABRI).
The total organization is as shown in Figure 7-1.

2) Because of the serious damage of the regency office, the chief of regency is taking command of the Headquarters for Disaster Countermeasures in the Governor's official residence.

3) Brigadier General Sulatin in the Udayana District(Head office : Denpasar) was dispatched to Maumere and is taking command of his own headquarters in Waioti Airport.

(2) Collection and Transmission of the Information

The government information seems to flow from sub-regency to upper organization.
Regency seizes detail informations such as human damage, building damage, the amount and distribution of supplies and name of contributors.
The countermeasures conducted by Provincial government has been unknown.
It seems that informations were not communicated well to the central government, probably due to the lack of the communication measures.
The ways to communicate at emergency is shown in Figure 7-2 .

(3) Medical Activity

1) The first-aid stations were placed in Maumere to give the first-aid treatment. Hospitals are still functional after the earthquake and the number of the patients coming to hospitals after December 12th is shown in Table 7-1.

2) There are good enough medical and pharmaceutical products supplied in Maumere Regency, which must be distributed to districts.

3) The relief supplies seems not to be received enough in Ende Regency because the road between Maumere and Ende was interrupted.

(4) Daily Living

1) Maumere (as of December 24th)

a) There has been no trouble in daily life since business services resumed and the relief supplies were arrived.

b) The waterworks were stopped for three days. Afterward, some main wells were broken and the capability of water supply was less than half compared with before. Now water supply is implemented with tank trucks.

c) Electricity and telephone services have been already recovered.

d) LPG and fire woods used as fuel seems to make the daily living little trouble.

2) Ende (as of December 23rd)

a) Though business services were resumed, the relief supplies from Maumere are not enough to be accepted in Ende because of interruption of the road between Maumere and Ende despite the operation of helicopters. Helicopter operation is conducted to distribute the supplies in mountain areas but the amount of distribution is limited.

b) Electricity and telephone services have been already recovered.

c) 5,000 units of tent accommodate 7,500 people.

(5) Tentative Accommodation

1) Most of the people are living in tents as tentative residence.

2) The lack of tents makes some people accommodated in open space like the style of camp. Approximately 100 tents are pitched in the field in front of official residence. Big tents of them are accommodated as many as 10 families (each family consists of 3 to 4 persons).

7-2 General of Restoration and Rehabilitation

(1) The emergency works (recovering minimum function) are being planned on completing up to the beginning of January and the rehabilitation works

(recovering full function) being planned up to the end of March.

(2) Some heavy construction machines such as bulldozer were offered by ABRI and rehabilitation works is about to be carried out practically.

(3) The rehabilitation of local public organizations and schools will be hoped to be conducted as soon as possible.

(4) It takes a long time to rebuild schools but big tents make school function possible. The target date of resuming schools is the beginning of January.

(5) The emergency works (recovering minimum function) for rehabilitation of public facilities like roads have been earnestly implemented to be completed by the beginning of January. The first priority is pointed to rehabilitation works for road between Maumere and Ende, which is now under process.

(6) Indigenous people start their own rehabilitation works by themselves.

7-3 Future Countermeasures

(1) It is really important for the government to offer urgent supports and actions such as accurate and rapid communication, medical activity, seize of transportation facilities and the provision of relief supplies when urgent works are required at disaster occurrence. Especially as for the information, the common forms, which the Ministries and Agencies related to disaster countermeasures posses, is indispensable to be prepared in parallel with strengthening communication network.

(2) It is urgently required to prepare the comparatively big tents for the tentative residence and those as wide as possible to accommodate about 40 pupils for school reopening.

(3) There are many people staying in their tents pitched in their houses' courts in fear of earthquake reoccurrence. It is necessary to investigate the damage of the houses as well as to explain inhabitants the characteristics of this earthquake and several after quakes in ease so that they can restart their own usual lives as same as before.

(4)It might be required to make a system which loans them to rebuild their lives and makes up the interest of the loan. There are some problems coming out of disasters to support the victims losing their jobs with job training and to aid the victims' lives.
The victims have led their evacuated lives for as long as more than one year and a half due to Mt. Unzen volcanic eruption in Japan. There are several examples to resolve the problems, which cannot be handled by existing law system, with the interest of the newly established fund. The donation must be considered to be made a good use.

(5)The area damaged by Tsunami this time is easy to be attacked again topographically. It should be necessary to make up the restoration plan for the damaged area in order not to be damaged again before the victims rebuild their houses disorderly.

(6)It was said that the number of residences living on low area along the sea has been increased gradually as there has been no huge Tsunami for seventy years. Besides almost all people do not have the idea, earthquake-Tsunami-evacuation. As a result, the damage was more seriously as expected.
It is essential to acquire proper knowledge and accurate information when earthquake and Tsunami occur. The public instruction on the behavior at earthquake and the comprehension on earthquake and Tsunami in childhood can reduce their damages compared with no recognition.

7-4 Recommendations

(1)The restoration plan, which includes disaster prevention, early rehabilitation and restart of the victims' lives, should be made especially in Wuring area urgently.

(2)The housing plan should be made urgently as not to force the damaged people into prolonging their temporal evacuation lives.

(3)The public instruction on disasters, diffusion of the knowledge on disaster prevention should be promoted strongly in order to make a people's proper action not only at earthquake but Tsunami with appropriate scientific understanding on earthquake and Tsunami.

IV. Summary of Recommendation

Recommendation on emergency countermeasures, further earthquake preparedness and earthquake study is described in chapter 3. The followings are its summary.

1) More dense seismic observation network is required to locate the hypocenter in good accuracy. At least the three-component seismometer should be equipped at each station and telemetry system is also necessary for real-time data processing. In order to examine the fault mechanism, a few broad-band seismic stations are also needed.

2) It is recommended to install strong motion acclerographs on ground and structure for evaluating strong ground motion and structural response.

3) Must evacuate from potentially dangerous area for tsunami as rapidly as possible after the earthquake. It must be strictly prohibited to approach to the shoreline to see the tsunami or the movement of boats.

4) The village in Babi Island was protected for the wind waves because of its location in the sheltered area of the island itself. However, it does not necessarily mean for the safety against tsunami. In Indonesia there are many island having the same natural conditions as Babi island. It is advisable to check the safety of these island againts tsunami.

5) The forests formed by palm trees or other trees must be protected because they are useful for reducing tsunami energy.

6) In the locations where high tsunami run-up was observed such as in Maumere, some signs showing the inundation height (usually recorded on the outside wall of the house) should be noticed in order to inform people of the danger of the tsunami and not to forget the tsynami disaster.

7) When people must live in the potentially dangerous area for tsunami as in the case of Babi Island, it is recomended to build shore protection facilities such as the coastal dike along the shoreline.

8) As the most emergent measure, it is required to fulfill school's function. Small sheet tents were set at almost of all damaged buildings. However big size sheets were not sold in Maumere city. At least one hundred tent sheets (10m x 10m) for temporary class room and black board etc. were urgently required.

9) In case of masonry structure, the stopping device for out-of-plane falling down of masonry wall is very important. To the damaged buildings, the assumption of rigid floor slab system can no be used. Seismic integrity of total structural system should be carefully considered.

10) Low cost strengthening of exiting masonry building is very difficult. Low cost repairing of slightly damage masonry building is also much difficult. It is required that such devices should be developped by well organised test research project.

11) One solution of much more seismic masonry structure is to add reinforced concrete seismic members or prestressed system. However this solution also oues to the smart loading test program.

12) It is recommended to carefully inspect the substructures of bridges with the major attention to the damage of substructures in Flores Island. For those bridges which suffered damage to the abutments in such a manner that the foundation slides to the deck side direction with the top of the abutment being tilted to the back fill side, it is recommended to fully replace the abutment as soon as possible to avoid the possible falling down on girder. Because those bridges are very old with only one lane evaluation needs to be made whether they should be repaired or replaced with new structures.

13) Because there are a number of bridges in Indonesia which were constructed at the age when the seismic effects were either disregarded or insufficient, it is recommended to develop the simple seismic evaluation method of existing bridge structures. The evaluation method has to be as simple as possible so that inspection be made at the sites. The evaluation of the seismic stability of substructures may be the key item to be considered. A master plan for seismic evaluation and possible strengthening of existing bridges may be important as a future plan.

14) Although it is generally very difficult to prevent the failure of cut and natural slope along the road in mountainous area, it is recommended to investigate the possible measures against slope failure from cost and effective point of view. It is advised at this point to

widen the road so that at least full two lanes of traffic be guaranteed. This may be effective to provide a space to store the falling soils and rocks from the above of the road during an earthquake. Covering the slope above the road by concrete mortar may be effective to prevent the weathering.

15) Because road network in Flores Island is very poor, it is recommended to established a master plan of future road network so that the major cities be prevented from isolation from other areas by an interruption at one location. Such a master plan may be very important for developing the Flores Island.

16) For restoring the Maumere port, it is recommended to consider the soil liquefaction effects in design. Some treatment for preventing the failure of the retaining wall may be effective to reduce the damage of wall and apron. It is also recommended to consider the soil liquefaction effect for reconstruction of important buildings in the port.

17) It is recommended to establish a system to systematically conduct the strong motion observation including the maintanance system. This may be very important to evaluate seismic design force and to evaluate soil and structural response during earthquake.

18) The characteristics of geology should be clarified when road plans are made whether the rocks are weathered or enoughly hard to decide the gradient of side slope.

19) 'Slope stake' is available to monitor the behaviour of landslides. This is very simple method.

20) Aerial photointepretation should be used more to compite various kinds of thematic maps for clarifying characteristics of the land and to catch natural disasters damages.

21) The restoration plan, which includes disaster prevention, early rehabilitation and restart of the victims' lives, should be made especially in Wuring area urgently.

22) The housing plan should be made urgently as not to force the damaged people into prolonging their temporal evacuation lives.

23) The public instruction on disasters, diffusion of the knowledge on disaster prevention should be promoted strongly in order to make a people's proper action not only at earthquake but Tsunami with appopriate scientific understanding on earthquake and Tsunami.

V. Acknowledgements

This work could not be completed successfully without the assistance and support provided by BACORNAS and SASTRAK.

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The team would like to extend their heartfelt to those who worked hard for the attainment of the team's objective.

Table 1.1 Selected destructive earthquakes with M=7 or more which caused damage to the Indonesian people.

Year	M D	h m	Lat	Long	M	Dead	津波有無	Remarks
1907	625	1754U	2.0	96.3	7.8		T	Indonesia(Sumatra):Gunung Sitoli(Nias)
1909	603	1841U	-2.5	101.5	7.5	200	T	Indonesia(Sumatra):Korintji Djambi (Ms=7.3)
1913	314	845U	4.5	126.5	8.3	some		Indonesia:Sangihe Is.(111人の村埋没)
1914	625	1906U	-4.0	102.5	8.1	many		Indonesia(Sumatra):Benkulen別資料死20 Ms=7.6
1921	911	401U	-11.0	111.0	7.5		T	Indonesia(Java)(Ms=7.5)
1931	210	634U	-5.3	102.5	7.1	18		Indonesia(Sumatra)
1932	514	1311U	0.5	126.0	8.3	5		Indonesia:Molucca Passage(別資料死者多数) Ms=8.0
1933	624	2154U	-5.5	104.7	7.5	76		Indonesia(S.E. Sumatra):Liwa (Ms=7.5)
1936	823		5.0	95.0	7.3	91		Indonesia(N.W. Sumatra)
1928	519	1708U	-1.0	120.0	7.9	8	T	Indonesia(Celebes):Dongala,Mambala (Ms=7.6)
1950	1008	323U	-3.7	128.2	7.6		T	Indonesia:Ceram Is. (Ms=7.4)
1950	1102	1527U	-6.5	129.5	8.1		T	Indonesia:Banda Sea (mB=7.4)
1963	1104	117U	-6.8	129.6	8.2			Indonesia:Banda Sea (mB=7.8)
1964	402	111U	5.8	95.6	7.0	110	T	Indonesia(Sumatra) (死者数は1/4と混同あるか)
1965	124	11U	-2.4	126.0	7.5	71	T	Indonesia:Ceram Sea,Sanana(Sulu)(Ms=7.5)
1968	810	207U	1.4	126.2	7.6		T	Indonesia:Molucca Passage (Ms=7.5)
1968	814	2214U	0.1	119.7	7.4	392	T	Indonesia(Celebes) (別資料死200)
1977	819	608U	-11.1	118.5	8.0	189	T	Indonesia:[Sumbawa Is.Eq.](Ms=8.1)
1990	418	1339U	1.1	122.8	7.4	3		Indonesia(Celebes):Bolaang-Gorontara a

T: tsunami

Table 2-1 Overall Damage

26 Dec. 1992

Regency	Population ('85)	Area	Human Damage				Building Damage				
			Dead	Injured Heavy	Injured Light	Missing	Office	Church Mosk	People House	School	others
	(Prs)	(km²)	(Prs)	(Prs)	(Prs)	(Prs)	(house)	(house)	(house)	(house)	(house)
Sikka	236,691	1,731.9	1,457	252	1,256	8	56	47	10,200	324	4
Ende	212,349	2,046.6	229	106	227	-	344	193	13,804	281	154
Ngada	188,353	3,037.9	18	2	4	-	67	45	1,194	100	68
Flores Timur	267,295	3,079.2	376	15	241	61	26	22	2,920	80	50
Total	904,688	9,895.6	2,080	375	1,728	69	493	307	28,118	785	276

Notice 1.Human damage (Dead) in Flores Timur includes about 200 victims by Tsunami.
2.Building damage (Housing) includes figures of houses partially damaged.

Source : Army's Headquarters for Emergency Activities in WAIOTI Airport in Maumere.
(Figures table which was prepared for the review to President in 23 Dec.1992.)

Table 3-3 Overall Damage in Sikka Regency

23 Dec. 1992

Sub-Regency	Human Damage			Building Damage								
	Dead	Injured		Govrnment Office			Civil Office			Church & Mosk		
		Heavy	Light	Totaly Collapsed	Heavy	Light	Totaly Collapsed	Heavy	Light	Totaly Collapsed	Heavy	Light
	(Prs)	(Prs)	(Prs)	(house)	(house)	(house)	(house)	(house)	(house)	(house)	(house)	(house)
Paga	14	7	14	-	71	14	67	45	38	-	3	2
Lekebai	7	9	27	57	4	2	1	2	-	8	2	1
Lela	13	16	64	12	13	9	4	7	12	4	2	1
Nita	16	42	116	15	22	5	36	5	8	3	8	1
Alok	142	205	1,155	10	41	10	67	45	38	2	8	5
Maumere	791	54	73	28	4	4	35	6	3	12	3	5
Palue	8	5	5	-	21	35	-	1	-	-	-	1
Kewapante	9	13	87	11	36	5	5	13	18	-	6	1
Bola	18	12	21	10	31	11	9	17	28	-	3	-
Talibura	82	27	30	25	39	10	-	-	-	14	8	4
Waigete	1	3	4	-	36	21	2	8	10	-	-	2
Sikka Total	1,101	393	1,596	168	318	126	226	149	155	43	43	23

Sub-Regency	Building Damage								
	Dewelling House			School			Toatal		
	Totaly Collapsed	Heavy	Light	Totaly Collapsed	Heavy	Light	Totaly Collapsed	Heavy	Light
	(house)	(house)	(house)	(house)	(house)	(house)	(house)	(house)	(house)
Paga	221	38	132	-	6	2	288	163	188
Lekebai	303	231	42	-	-	-	369	239	45
Lela	232	225	336	1	3	3	253	250	361
Nita	2,042	670	140	4	4	2	2,100	709	156
Alok	443	1,035	1,478	11	8	5	533	1,137	1,536
Maumere	3,413	325	174	3	1	1	3,491	339	187
Palue	48	105	69	-	-	-	48	127	125
Kewapante	228	279	255	3	7	1	247	341	280
Bola	117	104	79	-	3	2	136	158	120
Talibura	541	102	109	-	4	-	580	153	123
Waigete	31	401	119	-	4	2	33	449	154
Sikka Total	7,619	3,515	2,953	22	40	18	8,078	4,065	3,275

Source : The office of the Sikka Regency.

Table 2-3 Overall Damage in Ende Regency

22 Dec. 1992

Sub-Regency	Human Damage			Building Damage								Damage to Water Supply	
	Dead	Injured		Office	Church Mosk	People House	School	Student Inn	Shops	Inn	Total	Reservoir	Installation
		Heavy	Light										
	(Prs)	(Prs)	(Prs)	(house)	(house)	(house)	(house)	(house)	(house)	(house	(house)		
Ende	25	16	-	9	9	73	19	-	-	-	110	-	-
Ende Selatan	32	62	200	114	29	3,564	70	12	28	8	3,825	-	-
Ndona	30	32	62	35	23	813	42	1	-	2	916	27	12
Naga Panda	5	5	10	50	48	1,196	39	3	8	1	1,345	11	-
Detusoko	9	27	9	37	17	1,997	28	-	-	-	2,079	-	-
Wolo Waru	35	26	-	-	-	1,272	-	-	-	-	1,272	-	-
Maorole	21	4	50	43	22	2,250	31	2	2	-	2,350	2	-
Kotabaru	17	50	-	15	4	1,153	10	-	11	-	1,193	-	-
Watuneso	3	5	-	3	4	15	3	-	-	-	25	-	-
Wolojita	2	1	-	10	11	314	17	-	-	-	352	-	-
Weauvosa	14	-	-	8	3	540	2	-	-	-	553	-	-
Pukau Ende	-	-	2	9	3	155	5	-	-	-	172	-	-
Ende Total	193	228	333	333	173	13,342	266	18	49	11	14,192	40	12

Source : The office of the Ende Regency.

Table 7-1 Patient condition

(Prs)

Date	Visiting a hospital	Entering a hospital	Attending a hospital	Dead	Return home
12 Dec.'92	128	82	10	36	-
13	68	46	20	2	15
14	39	23	16	-	30
15	287	27	260	-	21
16	222	25	197	-	28
17	205	6	199	-	3
18	229	5	224	-	3
19	322	3	319	-	4
20	154	5	149	-	-
21	225	6	219	-	-
Total	1,879	228	1,613	38	104

Source: Army's Headquarters for Emergency Activities in WAIOTI Airport In Maumere.

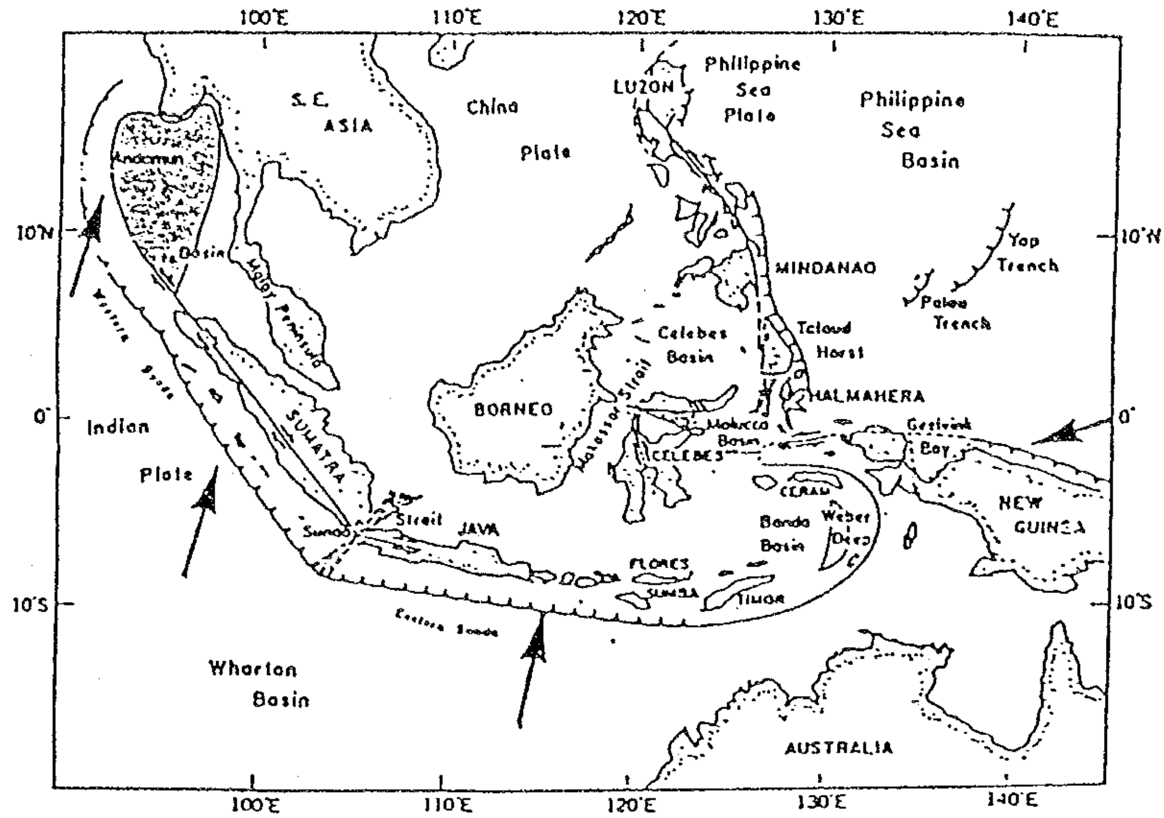


Fig. 1.1 Tectonics surrounding the Indonesian Islands.

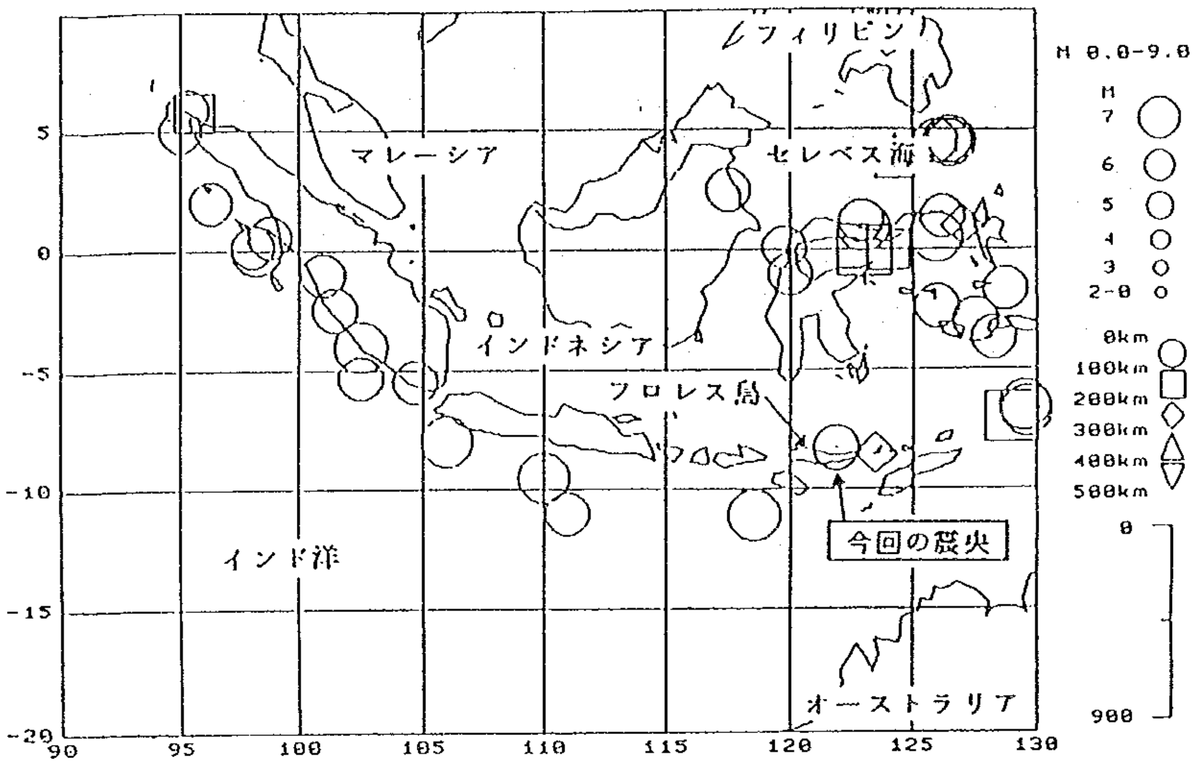
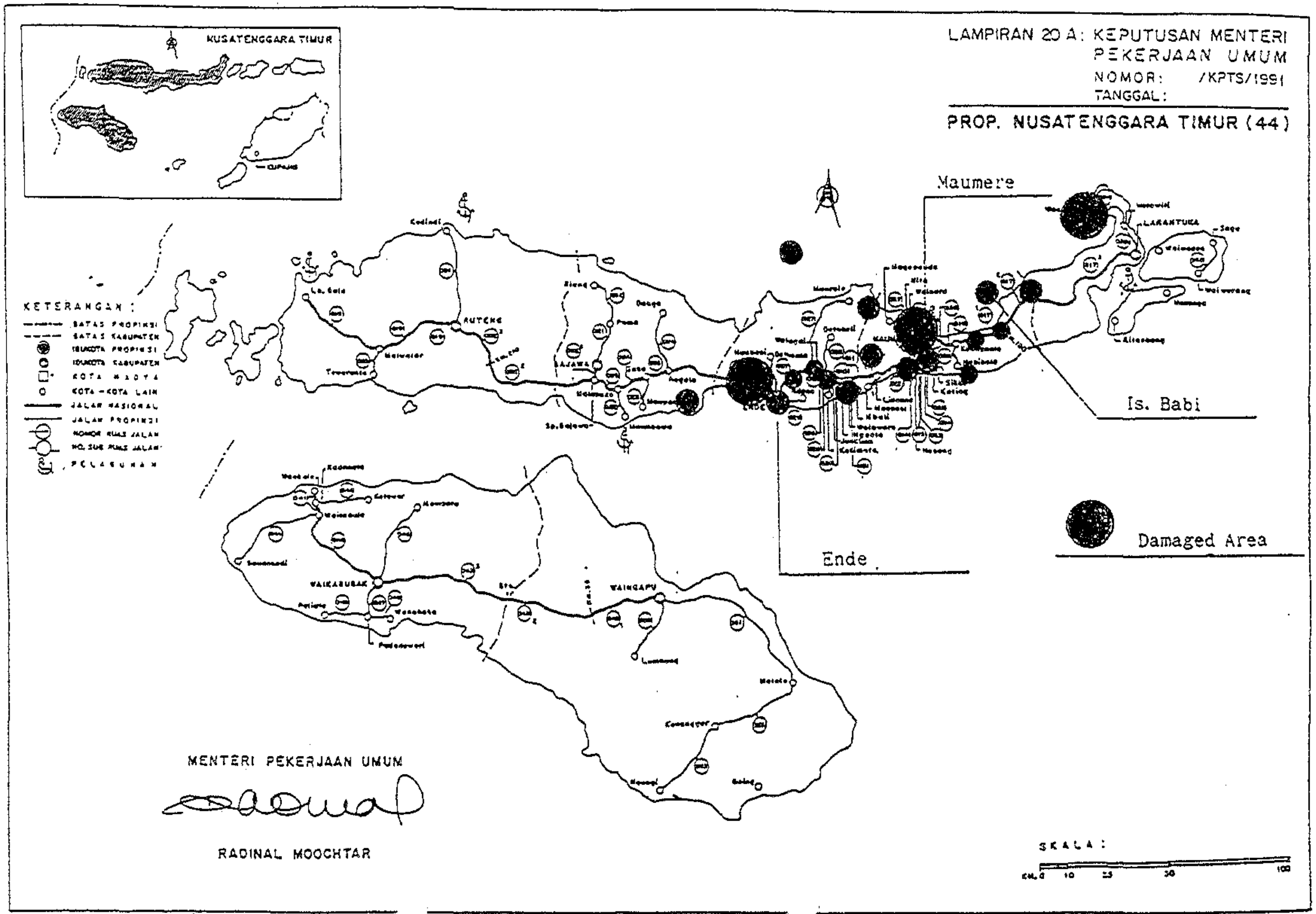
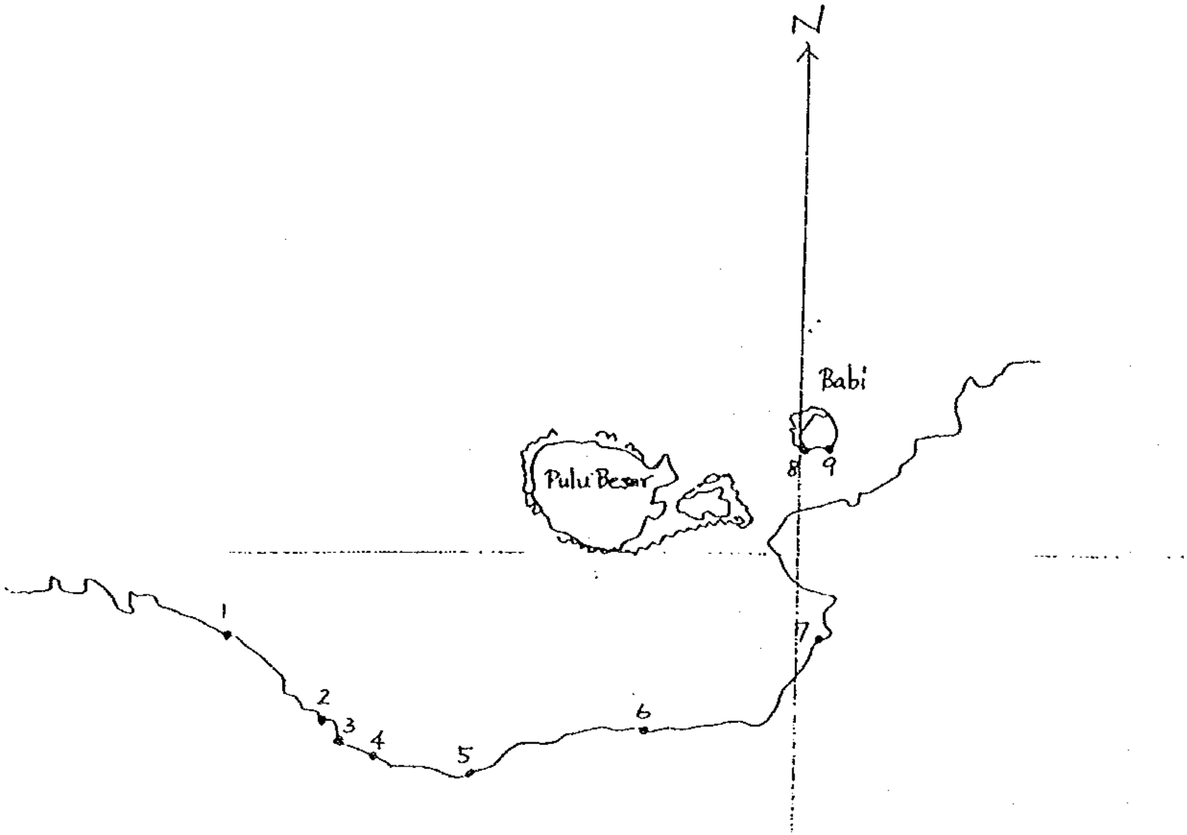


Fig. 1.2 Selected destructive earthquakes with M=7 or more.

Figure 2-1 Damaged Area





1.Nangahure	2.40 m	(Dec. 25, 11:29 am)
2.Wuring	2.75 m	(Dec. 23, 9:30 am)
3.Maumere Port	2.75 m	(Dec. 23, 8:30 am)
4.Waloti	2.55 m	(Dec. 23, 9:50 am)
5.(east of)Waipare	2.56 m	(Dec. 24, 7:00 am)
6.Waigete	2.40 m	(Dec. 23, 10:30 am)
7.Nangobrok	1.75 m	(Dec. 23, 11:30 am)
8.(west)Babi	3.40 m, 3.20 m, 3.00 m, 3.00 m, 3.00 m (Dec. 24, 1:12 pm - 1:45 pm)	
9.(east)Babi	3.40 m, 3.25 m, 3.43 m (Dec. 24, 3:14 pm)	

Figure 3-1 Location map and tsunami innundation height.

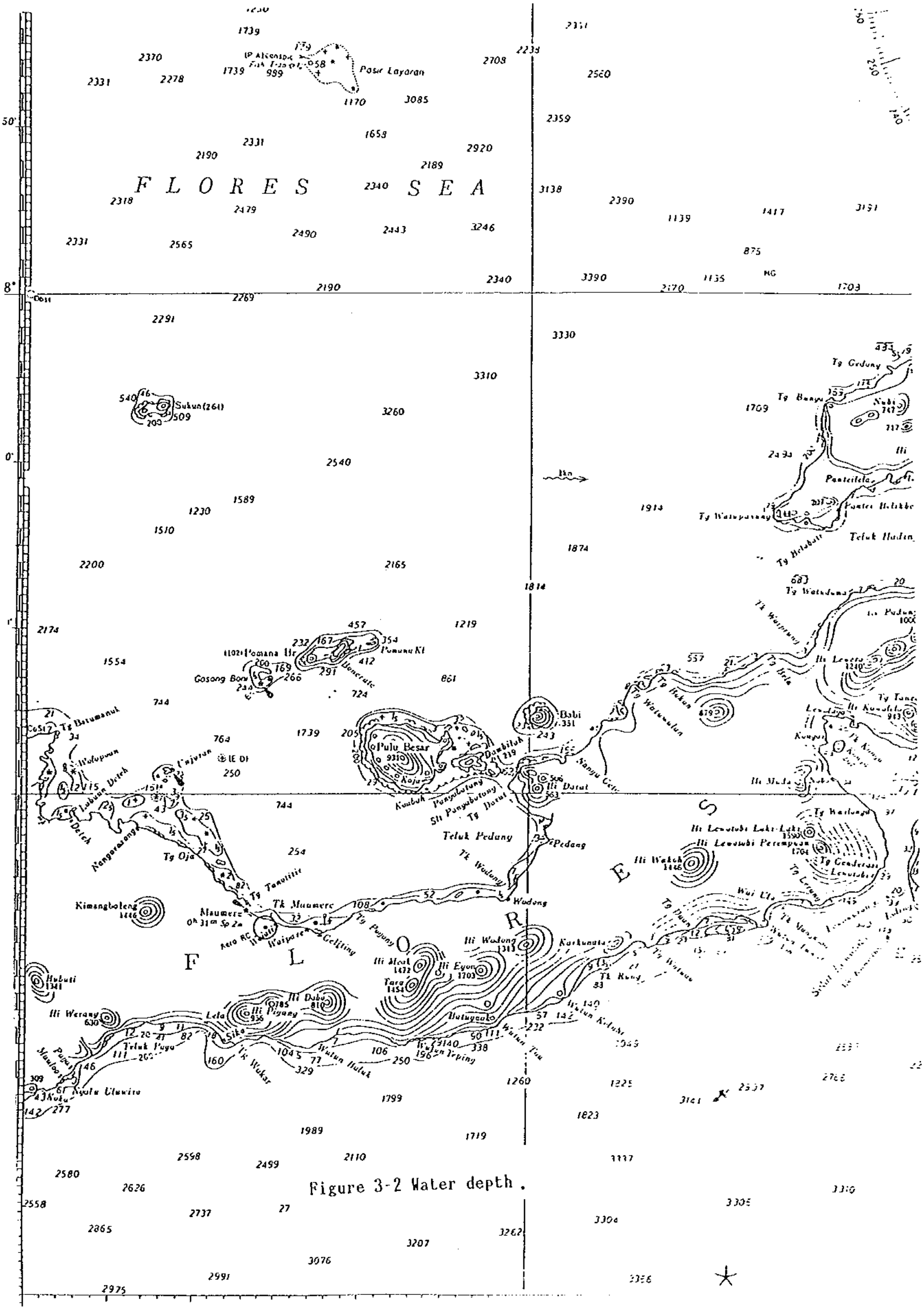


Figure 3-2 Water depth .

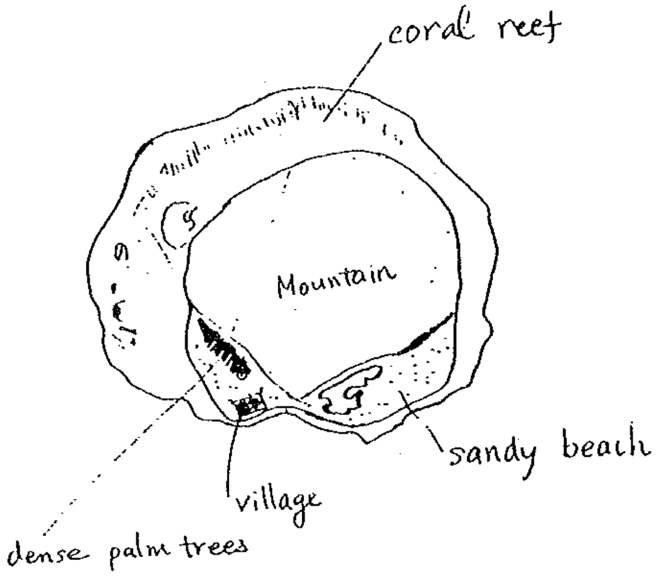


Figure 3-3 Topographic map of Babi Island.

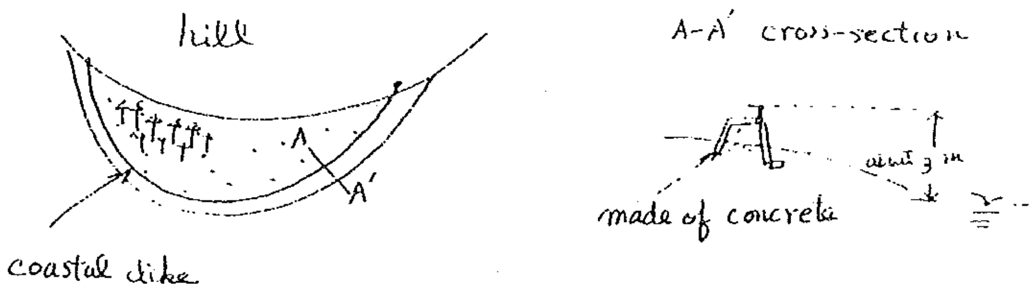


Figure 3-4 Schematic view of coastal dike.

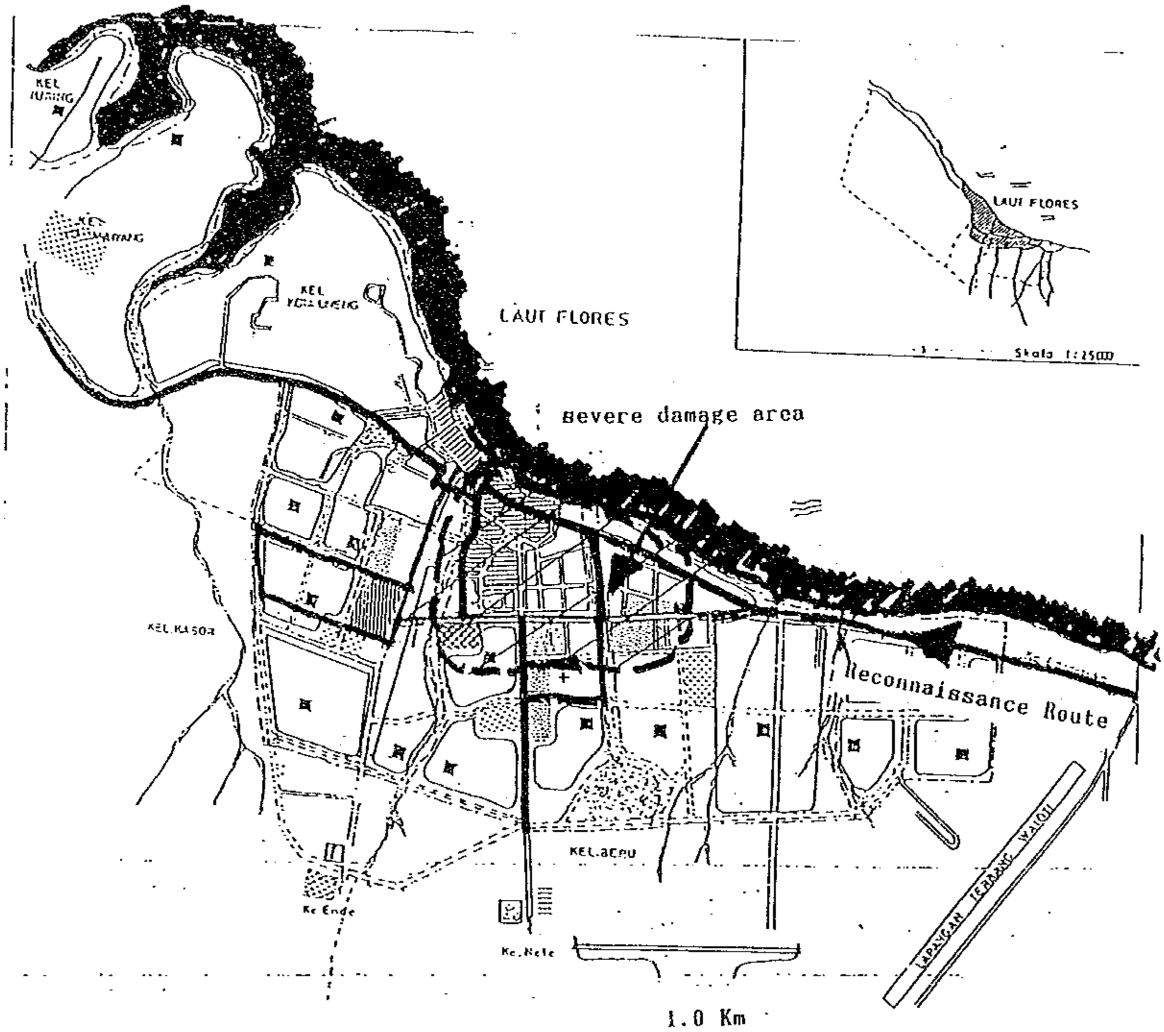


Fig.4.1 Maumere City Map

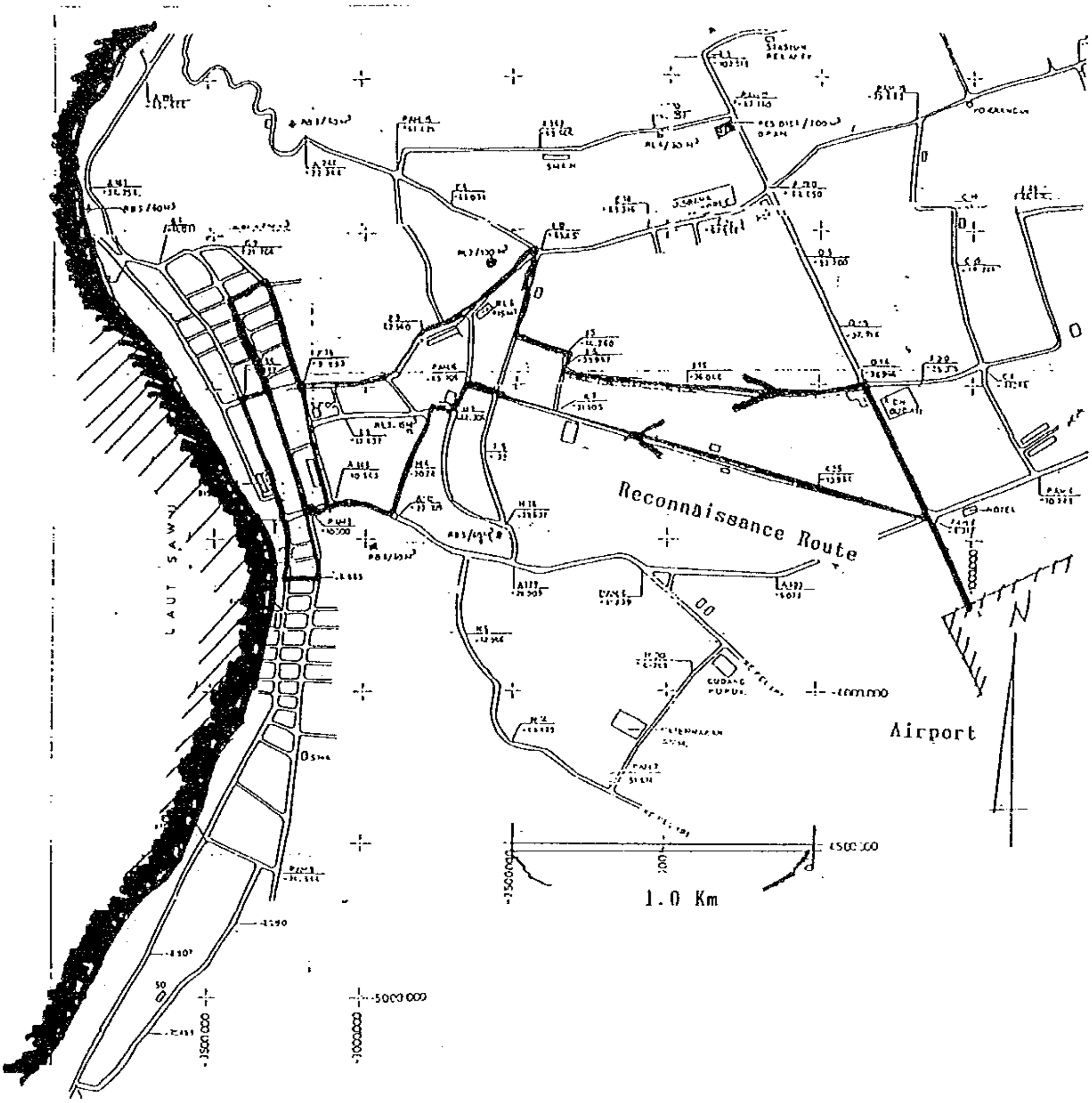


Fig.4-2 Ende City Map

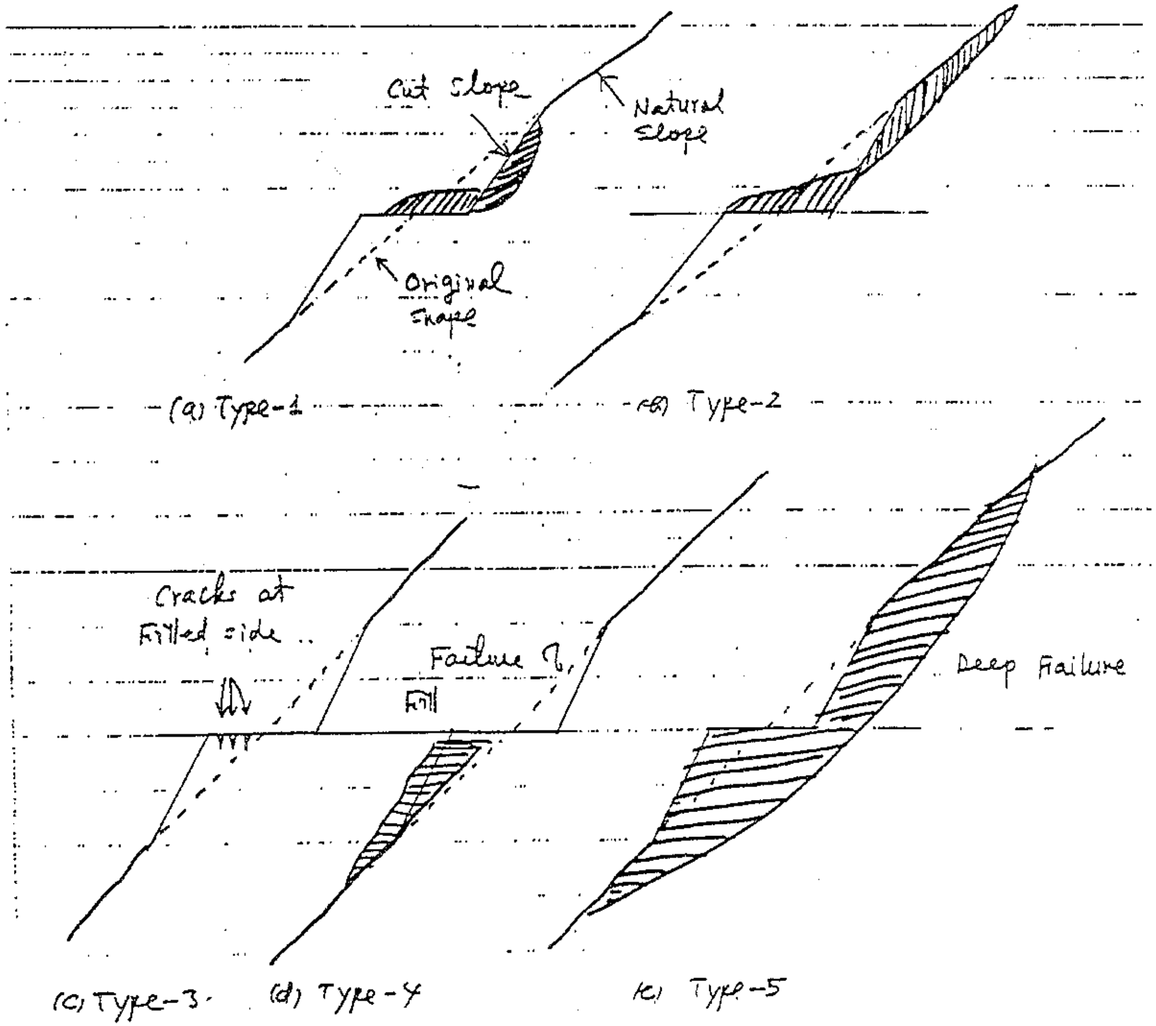


Fig. 5-1 Type of Slope Failure

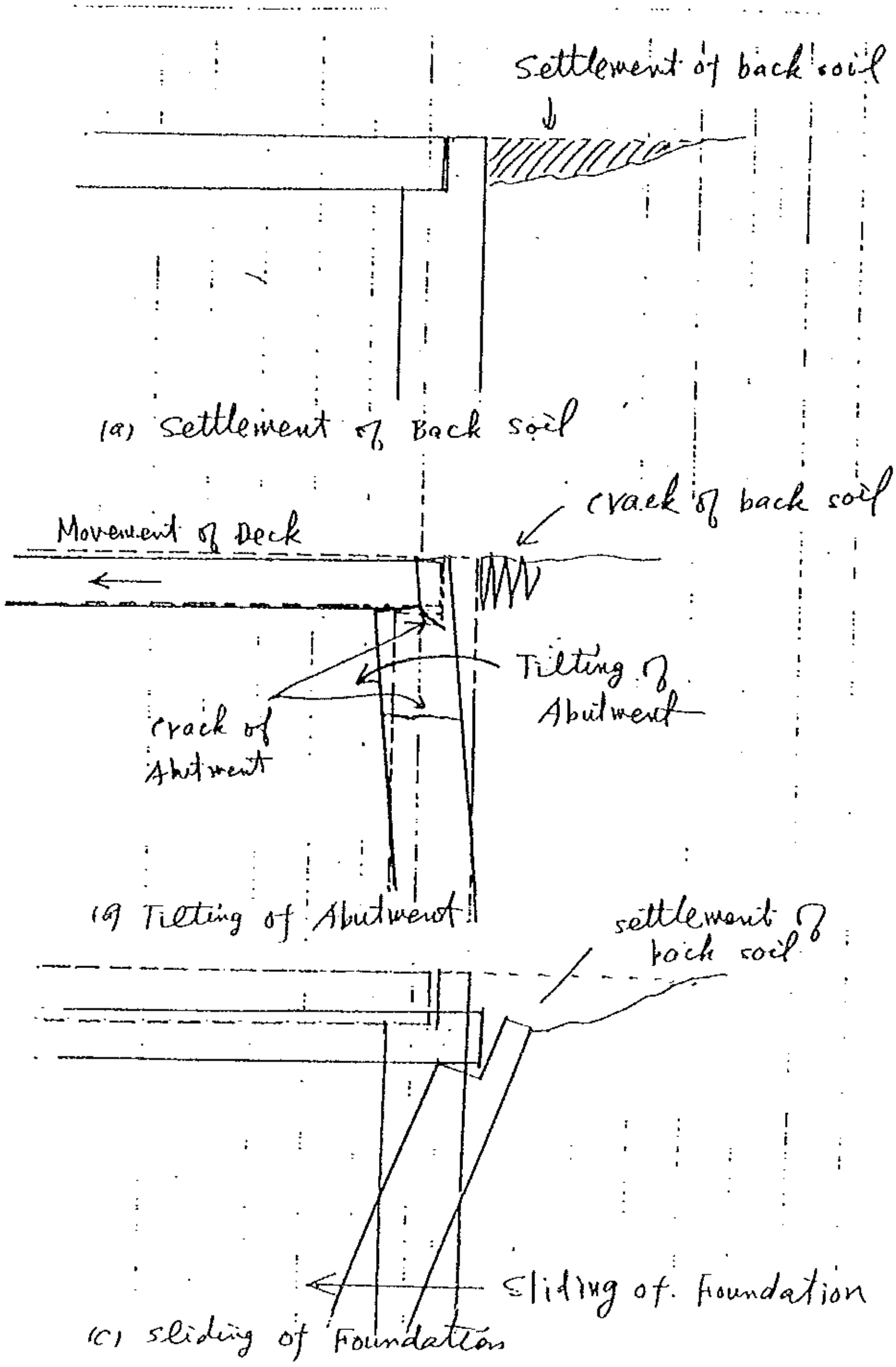


Fig. 5-2 Typical Damage of Abutment

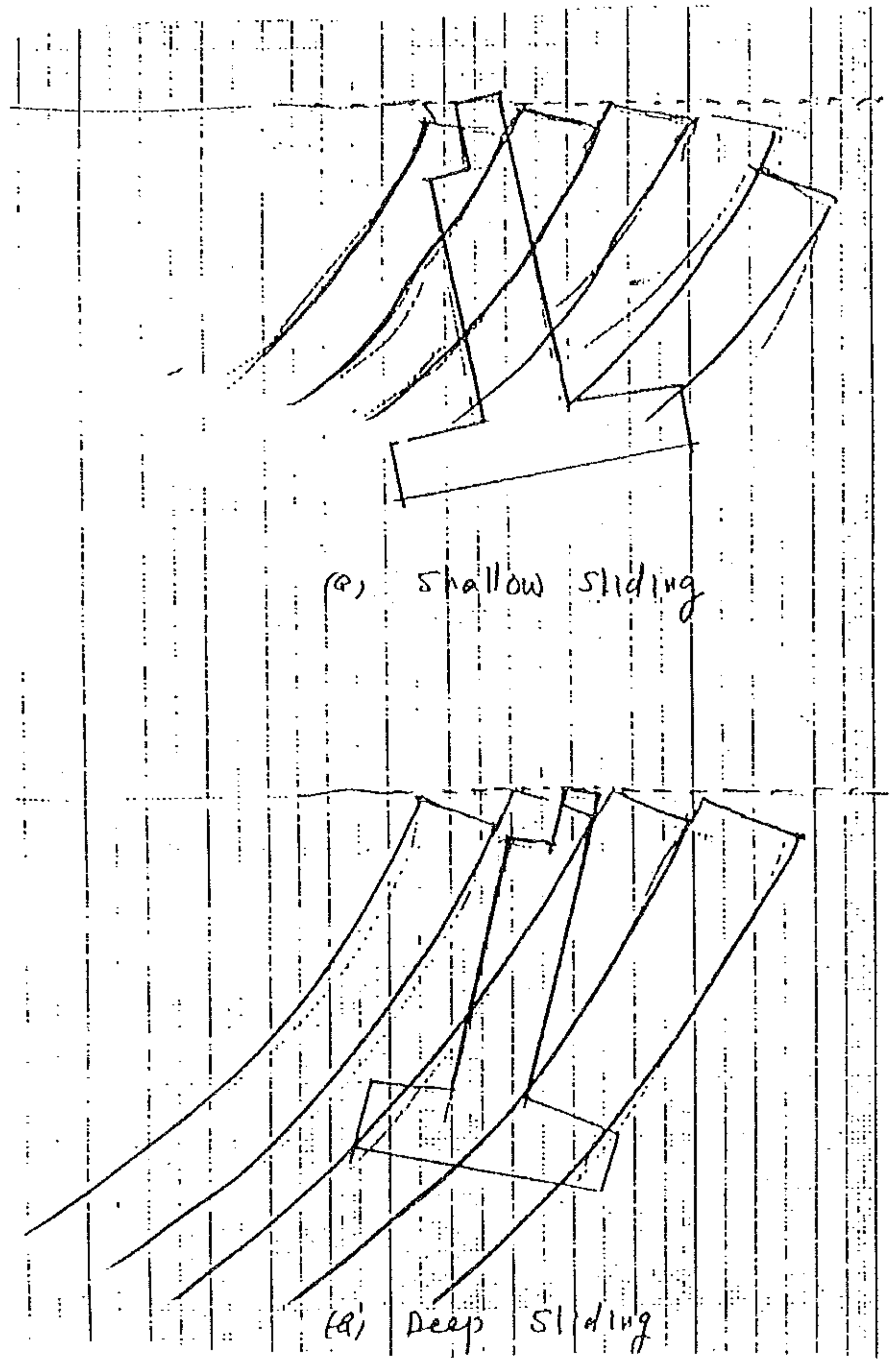


Fig. 5-3 Effect of Soil Sliding on Damage of Abutment

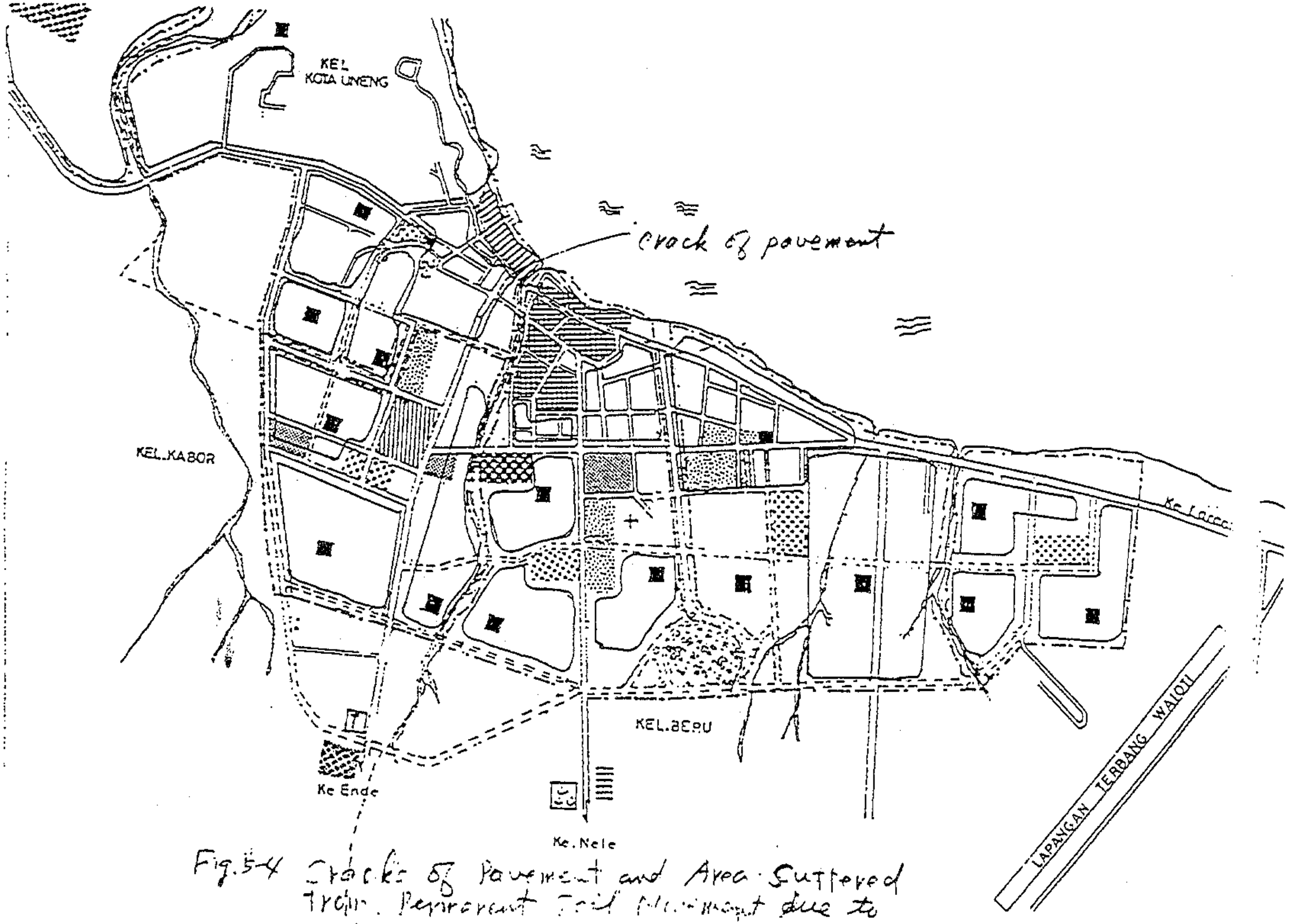


Fig.5-4 Cracks of Pavement and Area Suffered from Permanent Soil Movement due to Soil Liquefaction

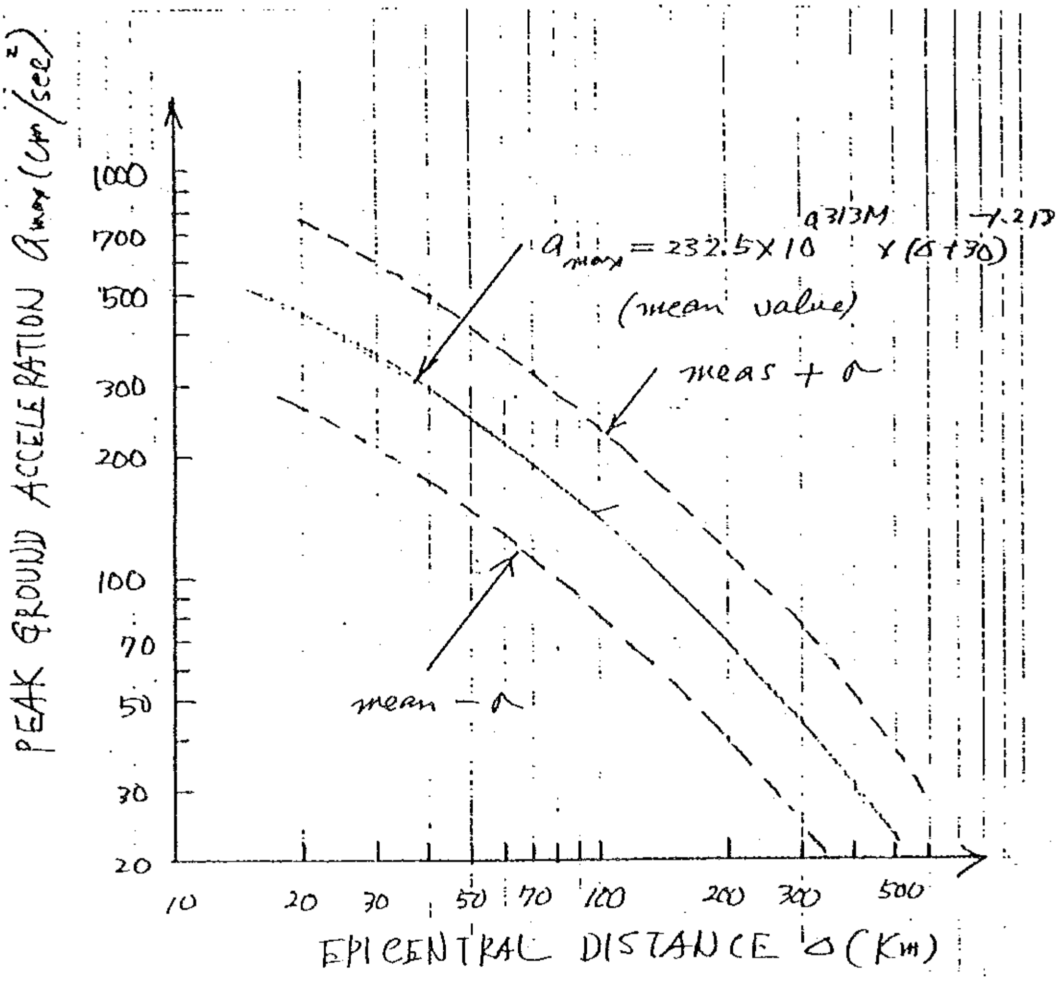
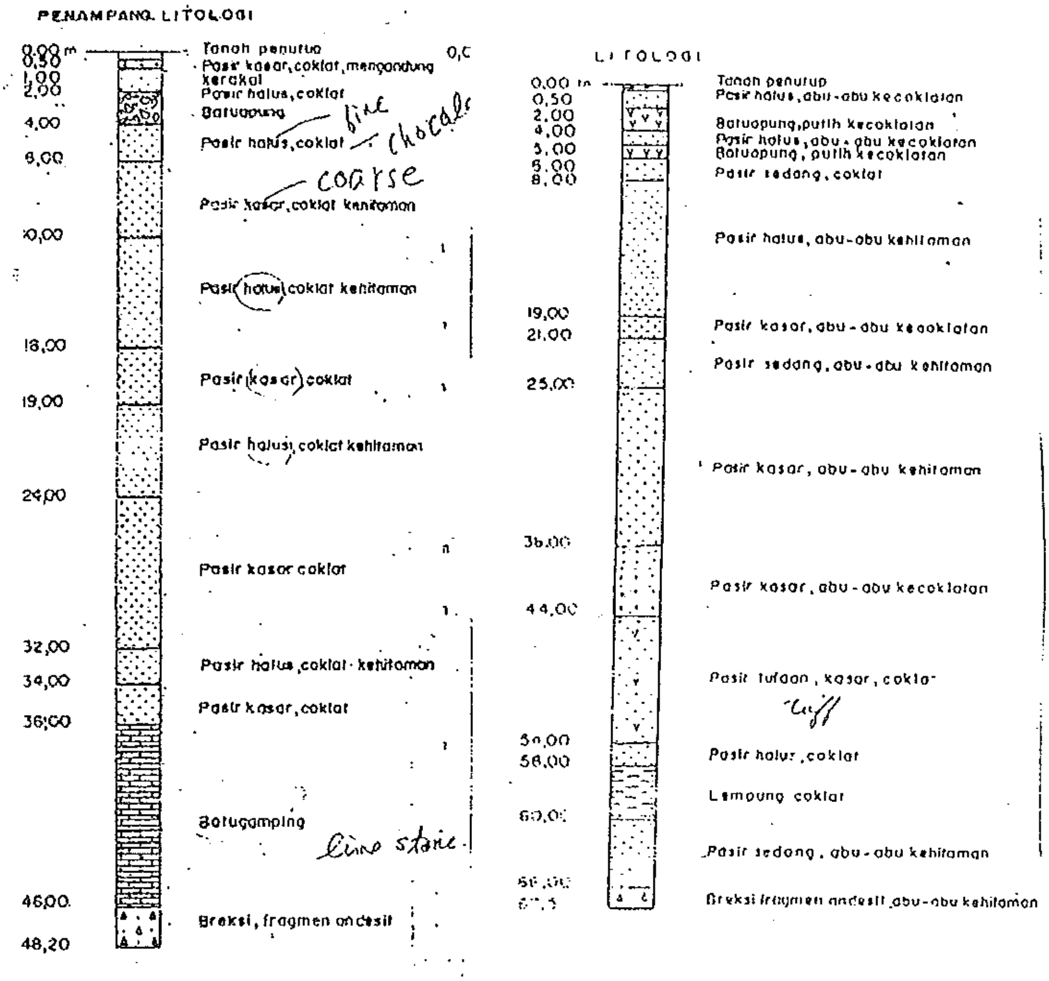


Fig. 5-5 Attenuation of Peak Ground Acceleration Based on a Japanese Empirical Attenuation Equation



(a) Point 1 (b) Point 2

Fig. 5-6 Soil Profile at Maumere

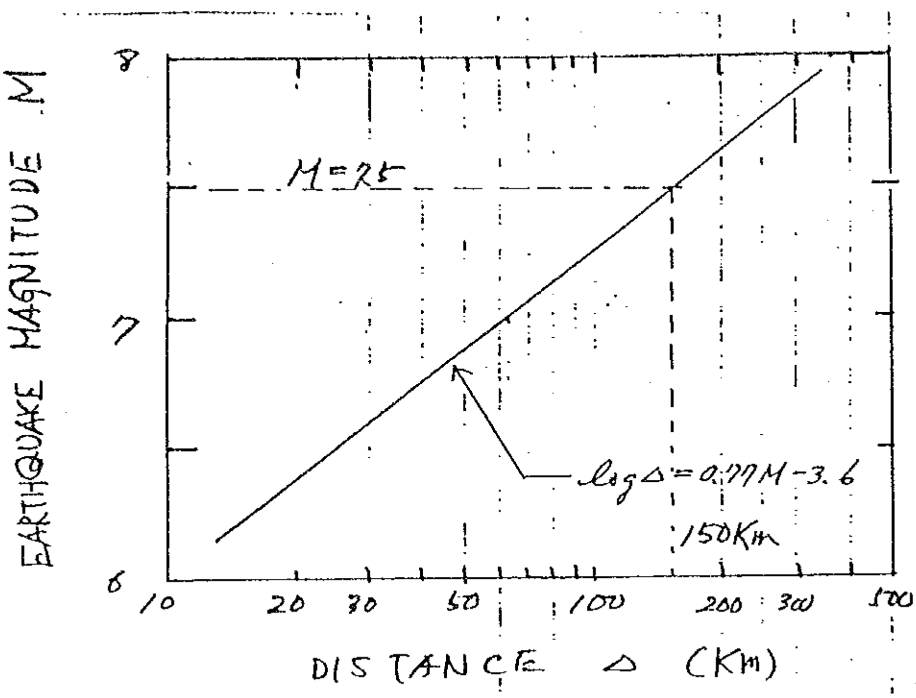


Fig. 5-7 Distance from Epicenter in which Soil Liquefaction was Developed in the Past Earthquakes

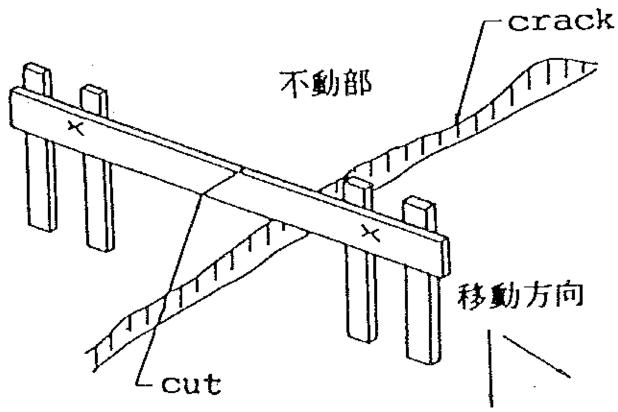


Fig.6-1　変位版
Slope Stake

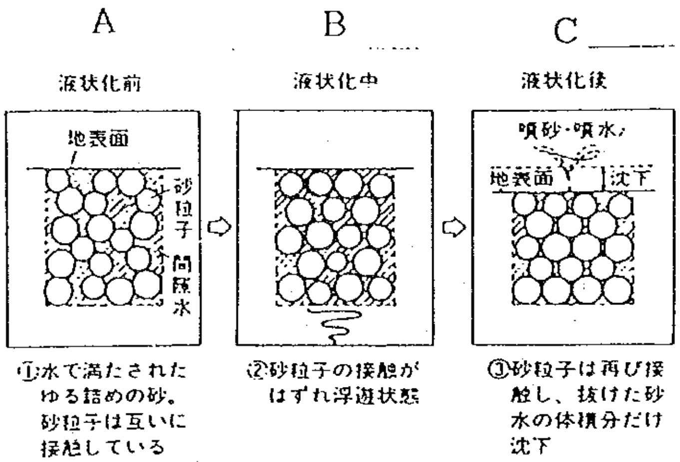
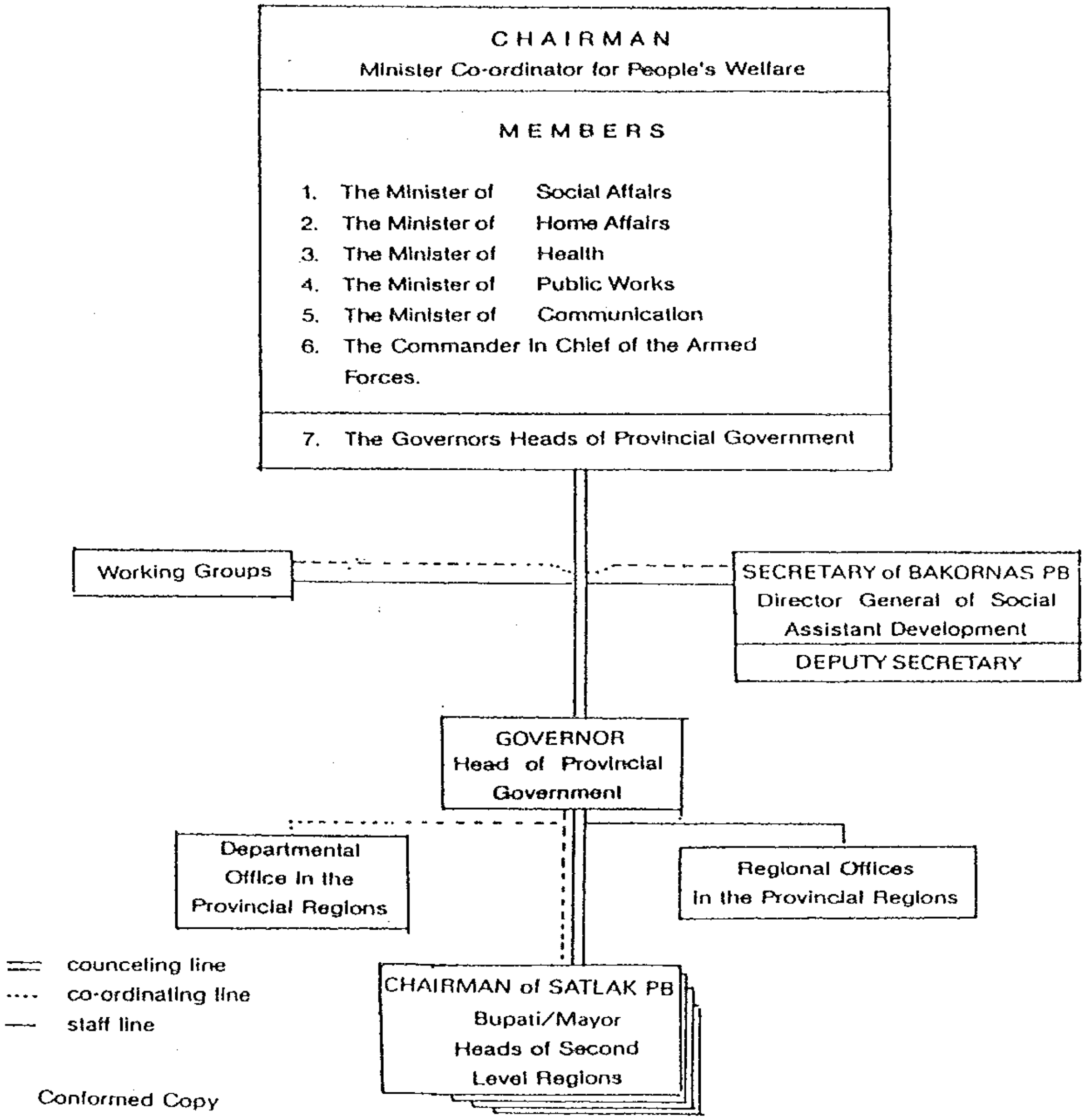


Fig.6-2 液状化発生前後の土粒子の状態[1]
Schematic illustration of soil particles before, during and after liquefaction.

Fig.A shows the condition beofore liquefaction, FIg.B show the condition in liquefaction, and Fig.C shows the condition after liqeufaction.

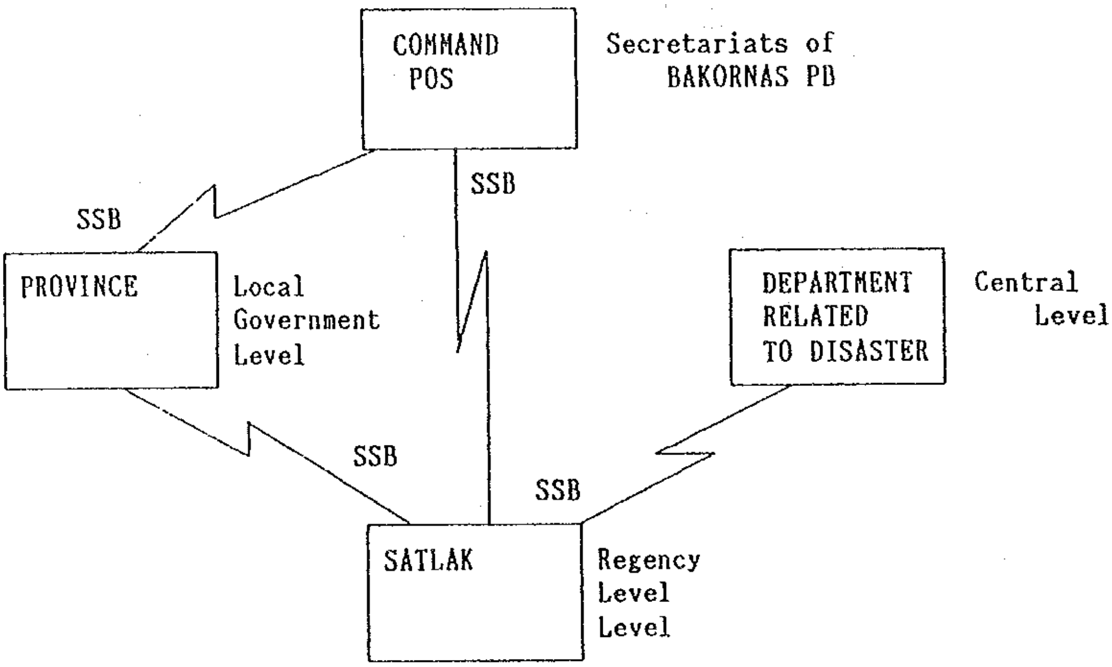
Figure 7-1

STRUCTURE DIAGRAM OF BAKORNAS PB ORGANIZATION
CHAIRMAN OF BAKORNAS PB



Conformed Copy

Figure 7-2 Disaster Communucation Network



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